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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See Advertisement page 28. 6462

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See Advertisement page 52, Nov. 22. 3402

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See half-page Advertisement page 58, Nov. 29.

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PATENT AND DESIGNS ACT, 1907.

Notice is Hereby Given that

FREDERICK ALEXANDER FLEMING, of 4, Mill Road, Cleethorpes, in the County of Lincoln, Engineer, late of 9, Ravensworth Crescent, Low Fell, Gateshead-on-Tyne, in the County of Durham, Engineer, Seeks Leave to Amend the Specification of Letters Patent, No. 23626, of 1913, granted to him for "Improvements in Winches for operating the rope of a Duplex Derrick."

Particulars of the proposed amendment were set forth in the Illustrated Official Journal issued on the 27th November, 1918.

Any person or persons may give notice of opposition to the Amendment by leaving Patents Form No. 18, at the Patent Office, 25, Southampton Buildings, London, W.C., within one Calendar month from date of the said Journal. R 190

W. TEMPLE FRANKS,
Comptroller General.

RECONSTRUCTION.

Association of Engineering AND SHIPBUILDING DRAUGHTSMEN.

Engineering Employers in need of Draughtsmen can get into touch with suitable applicants by sending particulars of their requirements and conditions to—

PETER DOIG, General Secretary,
8, Victoria Street, London, S.W. 1.

Employers are invited to use the facilities of the Association for this purpose.

R 221

UNIVERSITY OF BRISTOL.
DEMOBILISATION.

Special Regulations have been

made to allow intending students who have served in the war or in the scientific service of the war to be admitted to matriculation by vote of Senate on their educational qualifications, without formal examination; and also to allow of such students entering the University in January if candidates in Arts; in January, or between January and May, if candidates in Science, Medicine, Dental Surgery or Engineering; and if grounds be shown, counting their first year's attendance as though it had commenced in October. Engineering students in special cases may be allowed to count one whole year's attendance.

The Special Army Education Certificate qualifies for Matriculation.

Applications to the REGISTRAR. O 722

THE

Technical College,

LOUGHBOROUGH, LEICESTERSHIRE.

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None but first-class work of a productive character is undertaken by the students, working under the skilled supervision of a fully qualified technical staff.

The complete course covers a period of five years, during which works training in all the above sections will be given, and this will be accompanied by a full theoretical course of instruction in the College Lecture Rooms and Laboratories.

Intending students should be at least sixteen years of age, and have had a good Public School or Secondary Education.

The fee is £5 5s. per term, and the next term will commence on January 14, 1919.

Boarding accommodation is provided in Hostels attached to the College, full particulars of which, together with illustrated Prospectus, will be forwarded upon application to the Principal.

W. A. BROCKINGTON, O.B.E., M.A.,
Director of Education.

O 978

The Civil Engineers' APPOINTMENT BOARD,

8, PRINCES STREET, S.W. 1.
(Communications by letter only).

The Board, established in 1912, with the approval of the Council of The Institution of Civil Engineers, is Prepared to Register Applications for Professional Engineering employment from those attached to the Institution of Civil Engineers, and also in present circumstances, from persons accredited by other leading engineering Institutions.

The Board will be especially glad to place on its register qualified Engineers who have been released from the Forces and are seeking professional employment, or suitably educated men who contemplate engineering pupilage.

The Board invites inquiries from all employers who require the services of professional Engineers and also from Corporate Members of the Institute of Civil Engineers, particulars of any vacancies they may have for engineering pupils and apprentices. R 183

UNIVERSITY OF LONDON.

University College.

FACULTY OF ENGINEERING.

Arrangements have now been completed:—

(1) To enable students whose courses have been interrupted by War Service, to resume them as nearly as possible at the point at which they left off, by rejoining at the beginning of the Second Term, 13th JANUARY, 1919.

(2) To enable students who were unable to begin their engineering studies last October owing to War conditions, to begin them by entering next term, 13th JANUARY, 1919.

For both classes of students additional work will be provided during parts of the Easter and Long Vacations, so as to enable them to get in a full Session's work between January and August, 1919.

Students in either of these categories should apply at once to the PROVOST, University College, London (Gower Street, W.C.1.). R 196

Inst. C.E., I. Mech. E., B.Sc.,

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The Directors do not bind themselves to accept the lowest or any tender.

T. MORRISON,
Secretary.

Secretary's Office,
Amiens Street Station,
Dublin, 4th December, 1918. R 128

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By ORDER and for ACCOUNT of the MARSHAL of the ADMIRALTY.

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All further particulars may be obtained from the Selling Brokers, MORRISON, KEKEWICH & CO., 270, Gresham House, Old Broad Street, London, E.C. 2. R 207

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The material is excellent for building and road making purposes, and good wharf accommodation is available for barging away in loads of about 90 to 100 tons.

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The Committee do not bind themselves to accept the highest or any offer.

Town Hall, By order,
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11th December, 1918. R 311

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UNIVERSITY OF BIRMINGHAM.

FACULTY OF SCIENCE.

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Applications for the Chair of

CHEMISTRY, vacant by the resignation of Professor Percy F. Frankland, F.R.S.

The stipend offered is £1000 a year.

Applications may be accompanied by testimonials, references, or other credentials, and should be received by the undersigned, on or before the 8th February, 1919.

Further particulars may be obtained from
GEO. H. MORLEY, Secretary.
R 246

UNIVERSITY OF BIRMINGHAM.

FACULTY OF SCIENCE.

PROFESSORSHIP OF PHYSICS.

The Council of the University Invites

Applications for the Chair of

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The stipend offered is £1000 a year.

Applications may be accompanied by testimonials, references, or other credentials, and should be received by the undersigned, on or before the 8th February, 1919.

Further particulars may be obtained from
GEO. H. MORLEY, Secretary.
R 247

THE TECHNICAL COLLEGE, LOUGHBOROUGH.

H. SCHOFIELD, M.B.E., B.Sc. (Hons.) LONDON, A.R.C.Sc. LONDON, PRINCIPAL.

Wanted for the commence-

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Applicants should possess a University Degree with Honours in Mathematics, or its equivalent.

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W. A. BROCKINGTON, O.B.E., M.A.,
Director of Education. R 206

SWINDON EDUCATION COMMITTEE.

SWINDON & NORTH WILTS TECHNICAL INSTITUTION.

Principal: Mr. G. H. BURKHARDT, M. Sc.

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Applications for the perma-

nent APPOINTMENT of HEAD of the ENGINEERING DEPARTMENT of the Technical Institution. Teaching experience, including laboratory work, and practical experience in an engineering works essential, and ability to take some electrical work desirable. Salary according to new scale, which embodies the chief recommendations of the Government Committee. Applications to be sent before Saturday, December 28th, to the Principal from whom form of application, Salary Scale and further particulars may be obtained.

W. SHATON, Secretary.

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Required, Full-time Assistant

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Initial salary up to £250, according to qualifications, and thence by scale now under the consideration of the County Committee.

Service counts towards pension under the Teachers' Pension Act.

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H. SALTER DAVIES,
Director of Education.
December, 1918. R 148

ROYAL AIRCRAFT ESTABLISHMENT.

An Assistant Master is

REQUIRED for the Trade Lads' (Apprentices) Day School at the above Factory.

The subjects include Mathematics, English, Engineering Science and Drawing.

Further particulars may be obtained from the SUPERINTENDENT, R 99
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Applications are Invited for

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Mill Plant, non-ferrous metals, experience abroad desired but not essential, good salary for suitable man. State full experience, all information treated confidentially."—Address, O 933, Offices of ENGINEERING.

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—WANTED by an old-established firm of Bridge Builders and Constructional Engineers, a SALES MANAGER in their London office. Must have sound commercial ability, good knowledge of design and manufacture, and experience of home and foreign trade.—Apply, stating age, full details of career and salary, to R 233, Offices of ENGINEERING.

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REQUIRED for service in the Public Works Department, Straits Settlements, to prepare quantities, specifications and estimates for, and to supervise the erection of public buildings, roads, bridges, and other public works. Engagement for three years, with possible extension. Salary £360-£15-£480, with a duty allowance of £75 per annum. Free passages.

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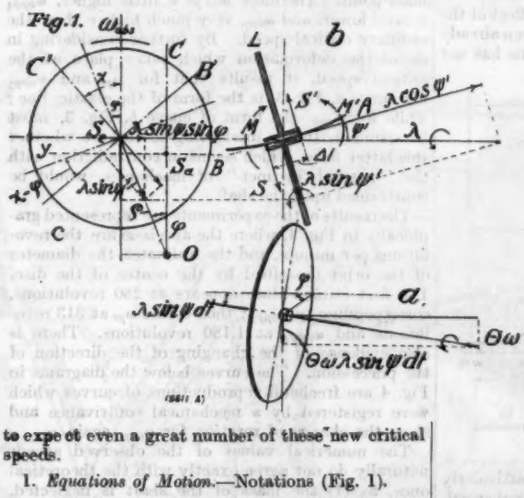
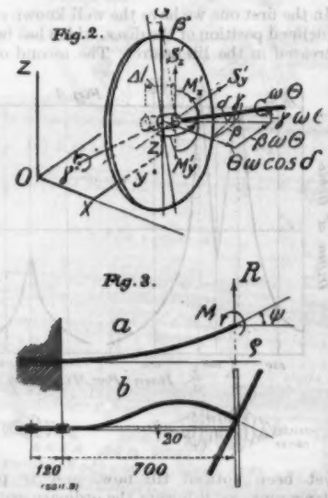
NEW CRITICAL SHAFT SPEEDS AS EFFECTS OF THE GYROSCOPIC DISC-ACTION.

By Professor A. STODOLA, Zürich, Switzerland.

EACH wheel of our great steam turbines forms an immense gyroscope, at least as far as we can consider it as being rigid. If a freely-rotating gyroscope be exposed to external forces (couples), its axis begins to move in a direction at right angles to the plane of the couple and, in special cases, describes a cone with a circle as base. This movement is called "precession." In the general case the precession is accompanied by a lateral vibratory movement, the "nutation." If the disturbance, under the effect of periodic forces, which very often are active in steam turbines (*e.g.*, by partial steam admission, or when the shaft suffers a "touch" in the intermediate stuffing boxes) is such as to increase more and more with increasing time, we have the phenomena of a critical speed. In what follows it will be demonstrated that this phenomenon, not observed hitherto, exists, and that for a shaft with many discs we have to expect even a great number of these new critical speeds.





1. *Equations of Motion.*—Notations (Fig. 1).

- L = The rotating disc, which may be supposed loose in its hub.
- ω = Angular velocity of the disc, remains constant as we suppose the friction being = 0.
- O = Point of intersection of the straight line joining centres of bearings with the disc plane.
- χ = Absolute angle of rotation in a very short time from the vertical position of a diameter.
- S_a = Centre of gravity, coinciding with centre of shaft, at the time $t = 0$.
- S_θ = Centre of gravity at the time $d\,t$.
- φ = Angle of rotation of the "radius vector" O S_θ.
- ψ = Angle formed by the tangent to the elastic line with the undeflected shaft, in the position S_θ.
- ψ' = The same in the position S_θ.
- ρ = Radius vector OS_θ.
- λ = $d\,\phi/d\,t$ angular velocity of the rotation of O S_θ.
- $\Delta\,l$ = The length of the hub.
- M₁M, S₁S = Bending moments and shearing forces at the extreme points of the length $\Delta\,l$.
- m = The mass of the disc.
- θ = Polar mass—inertia moment of the disc for the principal axis.
- θ_D = Mass—inertia moment of the disc in relation to a diameter. As we suppose the disc to be flat, it is $\theta = 2\,\theta_D$
- $\dot{} = \frac{d}{dt}$ *i.e.*, a point above a letter means its derivative with respect to the time.

The equation of motion is obtained by equating the increase of the impulse moment* in unit of time to the moment of force about the same axis. Considering the axis S_a Y the impulse moment for the time $t = 0$ is

$$H_{t=0} = \theta_D\,\dot{\psi} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In the position S_θ we must take the components of all impulse moments along the axis Y S_a. There is, firstly, $\theta_D\,\dot{\psi}'$, then the component of $\theta\,\omega$. In both the positions S_a and S_θ the angular velocity λ is resolved into λ cos ψ and λ ψ. The latter causes a rotation of the disc about the axis O S_a, so that the axis A will form the angle λ sin ψ $d\,t$ (Fig. 1*a*) with its original position. The impulse moment $\theta\omega$ therefore yields the component $\theta\,\omega\,\lambda \sin\psi\,d\,t$. The impulse moment $\theta_D\,\lambda \sin\dot{\varphi}$ resolved as in Fig. 1*c* yields $\theta_D\,\lambda \sin\psi_1 \sin\phi$ so we have

$$H_{t=dt} = \theta_D\,\dot{\psi}' + \theta\,\omega\,\lambda \sin\psi\,dt - \theta_D\,\lambda \sin\psi' \sin\phi \quad (2)$$

Now $\phi = \lambda\,dt$ and $\sin\phi \cong \phi$; ψ is also supposed small, so that $\sin\psi = \psi$; $\psi' = \psi$. The resultant moment of the external forces, positive in the sense in which the angle ψ increases, is $M_\psi = M^1 - M + (S^1 + S)\,\Delta\,l/2$, and so the first equation of motion becomes:

$$\frac{d\,H}{dt} = \frac{H_{t=dt} - H_{t=0}}{dt} = \theta_D\,\ddot{\psi} + \theta_D\,(2\,\omega\,\lambda - \lambda^2)\,\psi$$

$$= M\psi = d\,M + S\,\Delta\,l \quad . \quad . \quad . \quad (3)$$

The second equation of motion is obtained by considering the movement of the centre of gravity in polar co-ordinates ρ and φ. The acting forces S and S^1 are supposed to be always in a plane which passes through the centres of the bearings. This gives:

$$m\,\ddot{\rho} - m\,\lambda^2 = P_\rho = S^1 - S \quad . \quad . \quad (4)$$

The third one would be the equation for the acceleration of φ, which we omit, as we make no use of it.

If there is a single disc only on the shaft, and if it may be permissible to neglect the mass of the latter, we can express M_ψ P_ρ as linear functions of ψ and ρ. Under the further permissible assumption of $\Delta\,l = 0$ (3) & (4) will give:

$$\theta_D\,\ddot{\psi} + \theta_D\,(2\,\omega\,\lambda - \lambda^2) = M_\psi = a^1\,\rho + b^1\,\psi$$

$$m\,\rho - m\,\ddot{\rho}\,\lambda^2 = P_\rho = a\,\rho + b\,\psi \quad . \quad . \quad (5)$$

2. *The stationary movement i.e., the regular precession*, is characterised by $\ddot{\psi} = 0$; $\ddot{\rho} = 0$, and we have

$$\theta_D\,(2\,\omega\,\lambda - \lambda^2)\,\psi = a^1\,\rho + b^1\,\psi\,; \; -m\,\rho\,\lambda^2 = a\,\rho + b\,\psi \quad (6)$$

Now it is very important to note that the angular velocity λ can also have the opposite sense of ω. By repeating the above deductions under this assumption, we find for this "opposite precession":

$$\theta_D\,(-2\,\omega\,\lambda - \lambda^2)\,\psi = a^1\,\rho + b^1\,\psi - m\,\lambda^2\,\rho = a\,\rho + b\,\psi \quad (7)$$

For a given angular velocity ω we may calculate the values of ρ/ψ from the two equations (6); by equating them, we obtain an equation for the velocities λ of the regular precession. In the same manner we obtain from (7) the velocities for the "opposite precession."

When there are several discs on the shaft, with the inertia moments θ_1; θ_2 . . . and the deflections $\psi_1\,\rho_1$; $\psi_2\,\rho_2$; . . . then for each disc we shall have a pair of equations like (6) or (7), but the expressions for M_ψ and P_ψ will be very complicated. Thus for the first disc we should write:

$$\left.\begin{aligned} M_{\psi 1} &= a^1_{11}\,\rho_1 + a^1_{12}\,\rho_2 + \ldots + b^1_{11}\,\psi_1 + b^1_{12}\,\psi_2 + \ldots \\ P_{\rho 1} &= a_{11}\,\rho_1 + a_{12}\,\rho_2 + \ldots + b_{11}\,\psi_1 + b_{12}\,\psi_2 + \end{aligned}\right\} \quad (8)$$

The solution of the corresponding equations is very cumbersome, and will be treated by another method for a shaft with a great number of uniformly distributed discs.

3. *The Nutation.*—As we have supposed ρ and ψ as small quantities, the method of infinite small oscillations recommends itself for the investigation of the nutation. But as it is not certain, that the variation of ρ and ψ is small as compared with the values for the stationary condition, we pass to rectangular co-ordinates in Fig. 2. Notations:

- x y z = co-ordinates of the centre of disc which is also its centre of gravity.
- β, γ = supposed small angles which the tangent to the elastic line of the axis forms with the zox and yox planes.
- S_y' S_z' = the shearing forces acting at a distance $\Delta l/2$ in front of the middle plane of the disc.
- S_y S_z = the same at a distance $\Delta l/2$ behind the middle plane.
- M_y' and M_z' and M_y' M_z = the bending moments at the same points in the horizontal and the vertical planes.

The new equations of motion will be found as follows. The impulse moment for the axis z positive in that direction which makes β to increase, consists firstly, in neglecting small quantities of higher order, of the expression $\theta_D\,\dot{\beta}$; secondly, of the component of the momentum $\theta\,\omega$, which is $\theta\,\omega \sin\gamma \cong \theta\,\omega\,\gamma$. In the same way we get for the y axis the expression $\theta_D\,\dot{\gamma} - \theta\,\omega\,\beta$. Therefore the first system of dynamical equations is:

$$\left.\begin{aligned} \theta_D\,\ddot{\beta} + \theta\,\omega\,\dot{\gamma} &= M_\beta \\ \theta_D\,\ddot{\gamma} - \theta\,\omega\,\dot{\beta} &= M_\gamma \end{aligned}\right\} \quad . \quad . \quad . \quad (9)$$

As for the movement of the centre of gravity we have:

$$m\,\ddot{y} = P_y \qquad m\,\ddot{x} = P_x \quad . \quad . \quad . \quad (10)$$

and, of course, we have, also:

$$\left.\begin{aligned} M_\beta &= M_y^1 - M_y + (S_y^1 + S_y)\,\Delta l/2 \\ P_y &= S_y^1 - S_y \end{aligned}\right\} \quad . \quad . \quad (11)$$

Similar expressions are valid for M_γ P_x. If we put again $\Delta\,l = 0$, we may make use of the coefficients in (5) to express

$$\left.\begin{aligned} M_\beta &= a^1\,y + b^1\,\beta \\ P_y &= a\,y + b\,\beta \end{aligned}\right\} \quad . \quad . \quad . \quad (12)$$

On substituting (12) in (9) and (10) we obtain four simultaneous linear differential equations in the variables $y\,z\,\beta\,\gamma$, with constant coefficients, which can be solved by periodic functions of the time. We do not dwell upon this well-known method, in order to immediately proceed to the more important case of:

4. *Shaft with a Great Number of Uniformly-Distributed Discs of Equal Dimensions.*—We will imagine that each disc is divided into infinitely thin elementary discs, which are set apart at distances $d\,x$. In Fig. 2 Δl may now represent $d\,x$ and we denote for the unit of axial length by:

- θ_{p1} = The polar moment of inertia.
- θ_1 = The inertia moment relating to a diameter.
- m_1 = Mass of the discs.
- $y' = d\,y/d\,x$; $x' = d\,z/d\,x$.
- I = Moment of inertia of shaft cross-section.
- E = Young's modulus.

Then we must put in (9) and (10): $\theta = \theta_{p1}\,d\,x = 2\,\theta_1\,d\,x$; $\theta_D = \theta_1\,d\,x$; $\beta = y'$; $\gamma = z'$, and in (11): $S_y^1 + S_y = 2\,S_y$. Now the relation between y and the bending moment is

$$M_y = I\,E\,y'' \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Therefore

$$M_y' - M_y = d\,M_y = I\,E\,y'''\,d\,x \quad . \quad . \quad (14)$$

The first of the equations (9) thus becomes:

$$\theta_1\,(\ddot{y} + 2\,\omega\,\dot{z}') - I\,E\,y''' = S_y \quad . \quad (15)$$

As for the movement of the centre of gravity, we shall suppose that there acts, besides S_y^1 S_y, an *external periodic force*, which we shall write

$$P_e = m_1\,P_0 \sin k\,x \cos\lambda\,t\,.\,d\,x \quad . \quad . \quad (16)$$

so the first of equations (10) becomes

$$d\,x\,m_1\,\ddot{y} = d\,S_y + P_e \quad . \quad . \quad (17)$$

In (15) and (17) we eliminate S_y by substituting its value from (15) to (17) and we get:

$$-m_1\,\ddot{y} + \theta_1\,(\ddot{y}'' + 2\,\omega\,\dot{z}'') - I\,E\,y^{IV} + m_1\,P_0 \sin k\,x \cos\lambda\,t = 0 \quad . \quad (18)$$

Similarly for the co-ordinates z, but without any external force we have

$$-m_1\,\ddot{z} + \theta_1\,(\ddot{z}'' - 2\,\omega\,\dot{y}'') - I\,E\,z^{IV} = 0 \quad . \quad (18a)$$

The assumption as to the external force is so

* Moment of momentum.

chosen, that the solution of (18), (18A) is easy for a shaft supported freely at the ends. If we take:

$$\left.\begin{aligned} y &= B \sin k x \cos \lambda t \\ z &= C \sin k x \sin \lambda t \end{aligned}\right\} \quad . \quad . \quad . \quad (19)$$

and if, denoting by L the total length of the shaft, we make either:

$$k L = \pi, \text{ or } 2\pi, \text{ or } 3\pi \quad . \quad . \quad . \quad (19A)$$

then y, z, vanish for $x = o$ and $x = L$ and also M_y, M_z, in view of (13) vanish for the same values. Dividing (18) (18A) by m_1 and using the notations:

$$h = \frac{\theta_1}{m_1} k^2 ; \frac{I E k^4}{m_1} = \omega_k^2 \quad . \quad . \quad (20)$$

where ω_k means the ordinary critical angular velocity, the substitution of (19) in (18), (18A), gives:

$$\left.\begin{aligned} [(1+h)\lambda^2 - \omega_k^2] B - 2h\omega\lambda B + P_0 &= 0 \\ -2h\omega\lambda B + [(1+h)\lambda^2 - \omega_k^2] C &= 0 \end{aligned}\right\} \quad . \quad (21)$$

The "determinant" of these equations is:

$$D = [(1+h)\lambda^2 - \omega_k^2]^2 - 4h^2\omega^2\lambda^2 \quad . \quad . \quad (22)$$

and the solutions are:

$$\left.\begin{aligned} B &= -\frac{(1+h)\lambda^2 - \omega_k^2}{D} P_0 \\ C &= -\frac{2h\omega\lambda}{D} P_0 \end{aligned}\right\} \quad . \quad . \quad (23)$$

When D vanishes, B and C will become infinite and we have a critical speed. We can consider the equation $D = 0$ as one for ω or for λ; in the latter case there exists a critical value for the frequency of the external force. $D = 0$ can be written as:

$$(1+h)\lambda^2 - \omega_k^2 = \pm 2h\omega\lambda \quad . \quad . \quad (24)$$

or

$$(1+h)\lambda^2 \mp 2h\omega\lambda - \omega_k^2 = 0 \quad . \quad . \quad (24A)$$

whence we get:

$$\lambda = \frac{1}{1+h}\left[\pm h\omega \pm \sqrt{h^2\omega^2 + (1+h)\omega_k^2}\right] \quad (25)$$

which gives four values corresponding to the combinations: $\lambda_1 = + +$; $\lambda_2 = + -$; $\lambda_3 = - +$; $\lambda_4 = - -$. It is evident, that we have $\lambda_3 = -\lambda_2$; $\lambda_4 = -\lambda_1$; i.e., only two different critical periods. According to (21) we have in the case $D = 0$ always:

$$\frac{B}{C} = \frac{(1+h)\lambda^2 - \omega_k^2}{2h\omega\lambda}$$

and in consequence of (24)

$$\frac{B}{C} = \pm 1 \quad . \quad . \quad . \quad . \quad (26)$$

Therefore, in the proximity of "resonance" the centre of gravity moves in a circle in spite of the unsymmetrical disturbing force. When B, C, and λ are positive, the expressions (19) represent a circular movement in the same direction as the rotation ω. If C or λ be negative, the rotation is opposite. As can be deduced the former is the case with those λ of which the absolute value is great, the latter with the small value.

The solution (19) represents only the forced vibrations; if we make $P_0 = 0$ we arrive at the free vibrations of our system, which have the form:

$$\left.\begin{aligned} y &= \sin k x [B_1 \cos(\lambda_1 t + \epsilon_1) + B_2 \cos(\lambda_2 t + \epsilon_2)] \\ z &= \sin k x [B_1 \sin(\lambda_1 t + \epsilon_1) + B_2 \sin(\lambda_2 t + \epsilon_2)] \end{aligned}\right\} \quad (27)$$

with the following values of the roots of (24)

$$\left.\begin{aligned} \lambda_1 &= \frac{1}{1+h}\left[h\omega + \sqrt{h^2\omega^2 + (1+h)\omega_k^2}\right] \\ \lambda_2 &= \frac{1}{1+h}\left[h\omega - \sqrt{h^2\omega^2 + (1+h)\omega_k^2}\right] \end{aligned}\right\} \quad (28)$$

as can be verified by substitution. The constants B_1, B_2, ϵ_1, ϵ_2, are to be determined by the assumptions made as to the positions and the velocities of the disturbance at the beginning. With $B_2 = 0$ we have the regular precession with $B_1 = 0$ the same in the opposite direction. In the general case the movement represents the nutation of the gyroscope, and this consists in a combination of two circular motions, i.e., the centre of gravity describes a hypocycloidal path. If B_1 be $> B_2$, then the least distance of the centre of gravity from 0 is $B_1 - B_2$, the greatest distance is $B_1 + B_2$. The nutation has not the same importance as the forced precession described by (23), as in the absence of periodic external forces it will die out in consequence of the viscosity of the surrounding atmosphere.

Disturbing forces are always present, for where is a turbine which does not vibrate? Be it as small as it will, the elastic reaction of the foundation will set up external forces of period equal to the vibration. In the case of partial steam admission to one or more wheels, we may decompose the non-symmetrical frictional forces in the blades into a Fourier series, so that couples will appear with the frequencies of ω, 2ω, 3ω . . ., &c. It is easy to calculate the critical speed of any of these components. If, for example, we consider the chief disturbance, when:

$$\lambda = \pm \omega$$

then from equation (24) with the + sign we have for the regular precession

$$(1+h)\omega_{pr}^2 - \omega_k^2 = +2h\omega_{pr}^2$$

whence

$$\omega_{pr}^2 = \frac{\omega_k^2}{1-h} \quad . \quad . \quad . \quad . \quad (29)$$

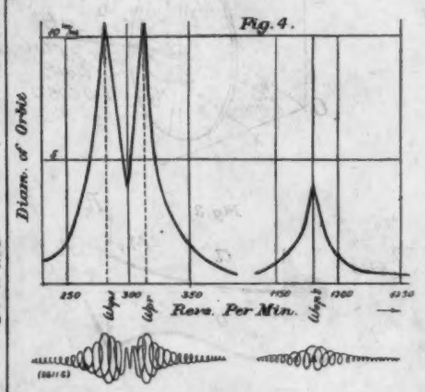
and for the precession in the *opposite direction* (equation (24) with the − sign)

$$(1+h)\omega_{opp}^2 - \omega_k^2 = -2h\omega_{opp}^2$$

whence

$$\omega_{opp}^2 = \frac{\omega_k^2}{1+3h} \quad . \quad . \quad . \quad . \quad (30)$$

In the first one we have the well-known effect of the inclined position of the discs, which has been already treated in the literature. The second one has not



yet been noticed till now, and is particularly dangerous, as it lowers the ordinary critical speed.

As ω_k is any one of the numerous critical speeds which can occur with flexible shafts, and uniformly distributed discs, so we have also theoretically an infinite number of the new gyroscopic critical speeds.

5. Control of the New Theory by Experiment.—A disc of 500 mm. diameter, and approximately 7 mm. thickness was supported on the end of a free shaft of 700 mm. length and 20 mm. diameter, see Fig. 3. By means of a crank on a parallel shaft, rotating always with the same velocity, from which a string was applied to the experimental shaft, there was exerted a periodic horizontal force in the neighbourhood of the disc. If we denote by R and M the reaction of the disc upon the shafts, then according to Fig. 3 we have:

$$\left.\begin{aligned} \rho &= \frac{R\beta}{3IE} + \frac{M\beta}{2IE} \\ \psi &= \frac{R\beta}{2IE} + \frac{Ml}{IE} \end{aligned}\right\} \quad . \quad . \quad (31) \quad . \quad . \quad (32)$$

whence

$$\left.\begin{aligned} R &= \frac{6IE}{\beta^3}[2\rho - l\psi] \\ M &= \frac{2IE}{\beta^2}[-3\rho + 2l\psi] \end{aligned}\right\} \quad . \quad . \quad (33) \quad . \quad . \quad (34) \quad . \quad . \quad (37)$$

The force and couple exerted on the disc, which we must put in equation (5) are $M_\psi = -M$; $P_\rho = -R$: therefore in confining the calculation to the "synchronous precession" with $\lambda = +\omega$ we have, according to (6),

$$\left.\begin{aligned} \theta_D \omega^2 \psi &= -M = \frac{2IE}{\beta^2}(3\rho - 2l\psi) \\ m\omega^2\rho &= +R = \frac{6IE}{\beta^3}(2\rho - l\psi) \end{aligned}\right\} \quad (35)$$

By taking the value of ρ from the first and substituting it in the second equation we have

$$\omega^4 + 2(\beta^2 - a^2)\omega^2 - a^2\beta^2 = 0 \quad . \quad . \quad (36)$$

$$\text{with} \quad a^2 = \frac{6IE}{m\beta^3}; \quad \beta^2 = \frac{2IE}{\theta_D l} \quad . \quad . \quad (37)$$

The positive root of (36) is

$$\omega_{pr}^2 = -(\beta^2 - a^2) + \sqrt{(\beta^2 - a^2)^2 - a^2\beta^2} \quad (38)$$

For the value $\lambda = -\omega$ we have, according to (7)

$$\left.\begin{aligned} -3\theta_D\omega^2 &= -M = \frac{2IE}{\beta^2}(3\rho - 2l\psi) \\ m\rho\omega^2 &= +R = \frac{6IE}{\beta^3}(2\rho - l\psi) \end{aligned}\right\} \quad (39)$$

whence $\quad 3\omega^4 - 2(3a^2 + \beta^2)\omega^2 + a^2\beta^2 = 0$

$$\omega_{opp}^2 = \tfrac{1}{3}[(3a^2 + \beta^2) \pm \sqrt{(3a^2 + \beta^2)^2 - 3a^2\beta^2}] \quad (40)$$

Both roots are positive, and so we have here two new critical gyroscopic speeds.

When a^2 is small as compared with β^2, we can develop the roots into the simplified expressions:

$$\left.\begin{aligned} \omega_{pr}^2 &= \frac{a^2}{2\left(1 - \frac{a^2}{\beta^2}\right)} \\ \omega_{opp1}^2 &= \frac{a^2}{2\left(1 + \frac{3a^2}{\beta^2}\right)}; \quad \omega_{opp2}^2 = \frac{2}{3}(3a^2 + \beta^2) \end{aligned}\right\} \quad (41)$$

We may also remark that $a^2/_3 = \omega_k^2$ equals the ordinary critical speed which considers the disc as a mass-point. Therefore ω_{pr} is a little higher, ω_{opp_1} a little lower, and ω_{opp} very much higher than the ordinary critical speed. By further considering in detail the deformation which takes place at the critical speed, it results that for ω_{pr} and ω_{opp_1} the curve *a*, Fig. 3, is the form of the elastic line; while for ω_{opp_2} the form of curve *b*, Fig. 3, must be assumed. It was interesting to observe whether this latter form, which seems in contradiction with the "natural instinct" of mechanics, would be constrained upon the shaft.

The results of the experiments are represented graphically in Fig. 4, where the abscissæ are the revolutions per minute, and the ordinates, the diameter of the orbit described by the centre of the disc. The first critical state appears at 280 revolutions, corresponding to ω_{opp_1}; then comes ω_{pr} at 313 revolutions and ω_{opp}, at 1,180 revolutions. There is also evidence of the changing of the direction of the precession. The curves below the diagrams in Fig. 4 are freehand reproductions of curves which were registered by a mechanical contrivance and show the change of rotation for ω_{opp} again ω_{pr}.

The numerical values of the observed speeds naturally do not agree exactly with the theoretical ones, as (1) the mass of the shaft is neglected, (2) the supports were not quite rigid, therefore the tangent to the elastic line was not horizontal at the bearing, (3) the disc is not an absolutely rigid gyroscope, (4) the centre of gravity does not coincide exactly with the centre of the disc. We postpone to another occasion the discussion of the influence these factors exert.

RECENT HARBOUR AND DOCK WORKS AT SINGAPORE, STRAITS SETTLEMENTS.

(*Continued from page* 606.)

EMPIRE DOCK AND RECONSTRUCTION OF WHARVES AT TANJONG PAGAR.

As already mentioned, the Empire Dock occupies the side of an old lagoon, called the "West Lagoon," into which the tide ebbed and flowed through a natural entrance, which previously occupied the site of the present entrance to the dock. Extending northward from the east and west ends of the "West Lagoon" were two branches of the latter named the Eastern and Western Swamps. These swamps, together with the "West Lagoon," are clearly indicated on Fig. 18. The whole site of the dock consisted of mud overlying substrata of clays and shale, except near the middle of the area, where the shale was practically bare. To the eastward and westward the shale dipped below the mud, reaching a depth of 60 ft. and more below L.W.O.S.T., along the site of the western wall.

An old road, crossing the site of the new works, and called the Keppel Road, connected Tanjong Pagar and Singapore, lying to the eastward of the dock, with Keppel Harbour lying to the westward, and is shown on Fig. 18.

The first operation in connection with the carrying out of the work was to clear the site of water. For this purpose a temporary dam was constructed across the old entrance to the lagoon, near the site

SINGAPORE HARBOUR WORKS; THE EMPIRE WET DOCK.

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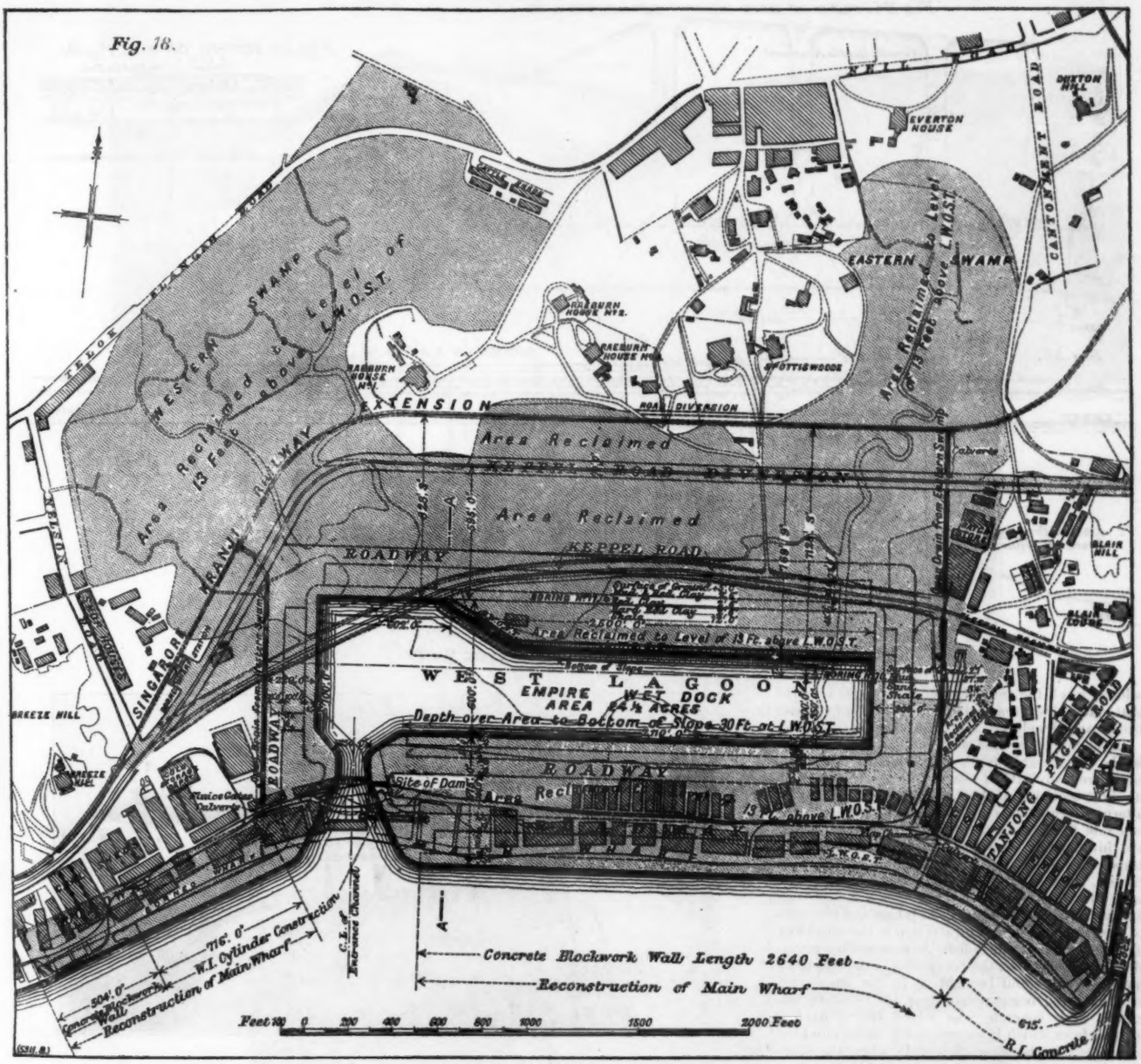
Fig. 18.



indicated on the plan. Simultaneously with the construction of this dam, two open drains, named the Western Drain and the Eastern Drain, were constructed, in order to deal with the water coming from the western and eastern swamps, which had previously drained into the "West Lagoon." Each drain was provided at its outlet with a self-acting tidal flap. The drains are shown upon the plan. The diversion of the Keppel Road, also shown upon the plan, was likewise put in hand, the east and west drains being carried under the road in culverts. As soon as the drains were completed, and the dam closed, the water was pumped out of the lagoon and the site dried, so that the construction of the works could be proceeded with.

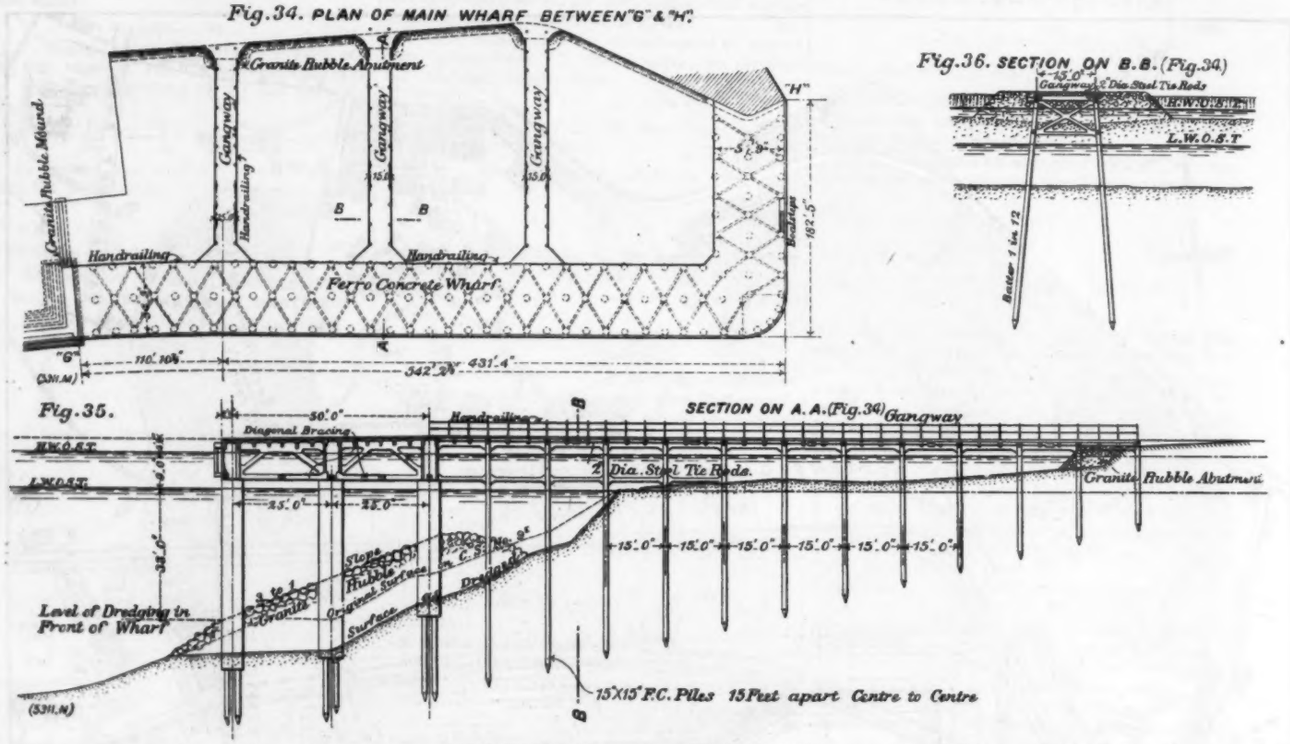
It will be seen from the plan that the dock, which has an area of 24½ acres, consists of a south quay, 2,110 ft. in length; a west quay, 700 ft. in length; a north quay, 602 ft. in length; and an east quay, 400 ft. in length. Between the north quay and the east quay, the northern boundary of the dock is formed with a slope, it having been considered by the Dock Board that quays would not be required over this length.

The widened portion at the west end of the dock allows of room for vessels to be manœuvred when entering and leaving the dock. An entrance 150 ft. wide is provided, having a bell-mouthed approach, as shown. A cross-section through the dock, showing the north and south quays, is given in Fig. 19, Plate XLIX. Fig. 20 shows the north and south quay walls to a somewhat larger scale. Fig. 21 gives a similar general cross-section taken further to the eastward, and shows the south quay and the slope on the northern side of the dock. Fig. 22 again shows the south quay and the northern slope to a larger scale. Fig. 23 gives in some detail a cross-section typical of all the dock walls. The depth of the foundations varied in accordance with the depth at which the shale was found, the width of the wall, of course, being also varied in accordance with the depth of the foundations. The walls consisted entirely of concrete in mass up to the level of about low-water neap tides. From that level upwards the wall was faced with small blocks of moulded concrete, and surmounted with a granite coping. At about low-water neap tide level a horizontal fender was fixed, consisting of a greenheart backing piece bolted into the concrete, this backing piece being faced with a rubbing piece of local ballaw timber, the latter being secured to the greenheart by means of coach screws. Details of the concrete ashlar facing and fenders are shown at Figs. 24, 25 and 26, on Plate XLIX.

A small scale typical elevation of these walls is shown on the left side of Fig. 28, under the description "east wall of entrance," but it is applicable generally to all the dock walls. The walls were carried out in timbered trenches sunk through the mud until the shale was reached. Where the shale was met with at a comparatively high level the walls were carried down to a minimum depth as shown on Fig. 23. Where, however, the shale had dipped to

RECENT HARBOUR AND DOCK WORKS, SINGAPORE.

MESSRS. COODE, MATTHEWS, FITZMAURICE AND WILSON, AND MR. J. R. NICHOLSON, M.M.INST.C.E., ENGINEERS.



FIGS. 34 TO 36. REINFORCED-CONCRETE WHARF.

a lower level, the trenches were carried down until that material was reached, the foundation of the wall being carried well into the solid bottom.

In the case of the east, west and north walls, owing to the considerable depth of overlying mud, it was considered advisable to carry out the trench work in short sections of about 100 ft. or so in length, alternate sections being first completed, and the concrete brought up to about ground level before the intermediate sections were put in hand. In these cases, each section was surrounded by whole timber, grooved, and tongued sheet piling, driven well down into the shale. The material was then excavated from inside the sheet piling and the sides of the trench timbered and strutted in the usual way as the excavation proceeded. As soon as the excavation was completed, the concrete was deposited by means of skips and brought up in the usual way, the timbering being removed as the concrete was raised. The concrete was mixed in mechanical mixers, from which it was carried in skips mounted on trolleys to the place of deposit, where the skips were lowered by means of a crane and the concrete placed where required. Gantry cranes spanning the trenches were used, both for this purpose and also for removing the excavated material.

Simultaneously with the carrying out of the walls, as above described, the main excavation of the dock was proceeded with. The material consisted chiefly of mud, though over a considerable area of the dock, the excavation was made in clay or shale. The work was carried out in two lifts, steam navvies being employed to a considerable extent, though a large portion was removed by hand-filling gangs. The better-class material was reserved for the filling immediately behind the walls and for filling in the area between the northern side of the dock and the Keppel Road diversion, the soft material being taken for the purpose of reclaiming the eastern and western swamps, with the result that a large area of valuable land has been rendered available for future use by the Board. The extent of the general filling around the dock is shown on Figs. 18, 19 and 21. In

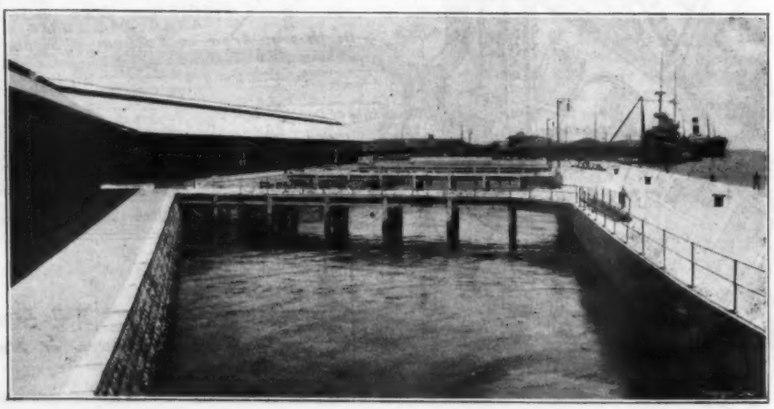


FIG. 41. REINFORCED-CONCRETE WHARF AS COMPLETED.

Fig. 22 is given a typical section of the slope, forming the northern margin of the dock. Where the shale occurred, this was simply trimmed off to the required slope. Above that level a bank of selected filling was first tipped, the dock face being protected by a pitched slope formed of small moulded concrete blocks laid upon a bed of broken stone.

The Keppel Road diversion was formed by tipping in the first instance a bank of selected material to the required width upon the natural surface of the ground. When settlement and consolidation had taken place to a sufficient extent, the roadway was metalled and well rolled in the usual manner, the tramway lines being also laid and connected up with the main service.

The quay surfaces for a distance of 45 ft. back from the cope were also metalled and rolled to the required slopes in the same manner as the Keppel Road. Behind this quay surface, foundations were prepared for sheds or godowns 50 ft. in width along each of the dock quays. These foundations consisted of broken granite thoroughly well rolled and consolidated, upon which a layer of concrete in mass was deposited to form the floor of the sheds. The sheds themselves consisted of wrought-iron framing, with roof and sides of galvanised sheeting. The floor surface slopes up from front to back at an inclination of 1 in 60, so that at the back of the godowns the floor is at a convenient level to form a platform from which railway trucks and carts can be loaded. The roofs project on either side in the form of wide eaves, that on the front giving shelter from the rain for the storage of rough goods, that on the back giving similar shelter for the loading of trucks and carts. They were erected by the Board, as required, and did not form part of the contract.

Railways of metre gauge are also provided along the backs of the sheds, connecting with the

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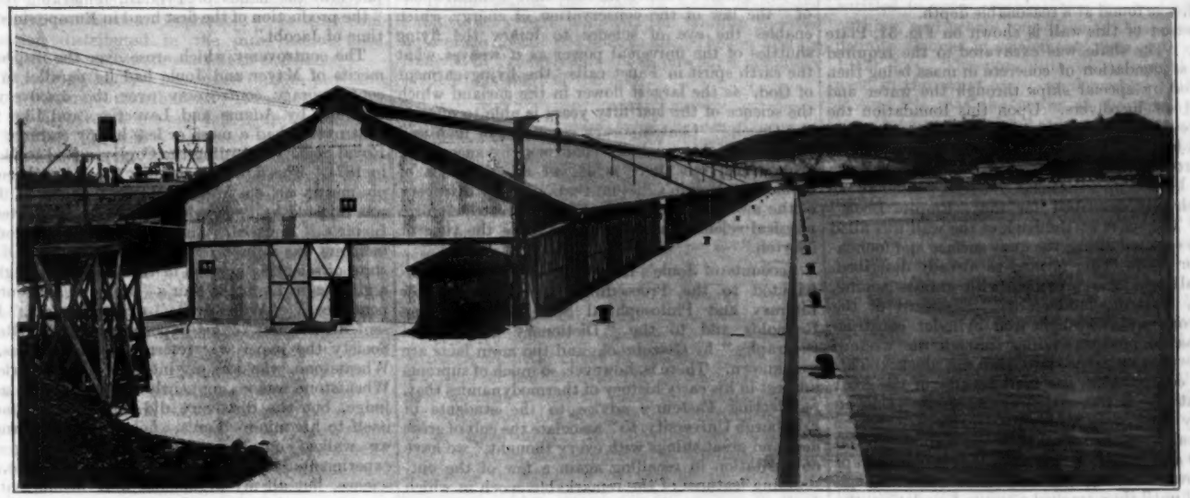


FIG. 37. THE EMPIRE DOCK, SOUTH QUAY.

FIG. 38. WROUGHT IRON CYLINDER CONSTRUCTION.

Federated Malay States railway system. Up to the present, railways have not been laid along the quays in front of the sheds, but provision is made for them if ultimately found to be necessary. Mooring bollards, ladders and boat steps are provided at convenient intervals.

The concrete for the walls consisted of broken granite, sand and cement. The granite was obtained from quarries in the island, where crushers were also provided for breaking the stone to the required size, whence it was brought down by rail to the site of the works. The sand was obtained from different spots along the foreshore of Singapore Island, and other islands in the neighbourhood. The cement for the most part was obtained from England, some having been obtained from Green Island, Hong Kong. The whole of the cement passed the requirements of the British Engineering Standards Specification.

The photographic view, Fig. 37, shows the south quay of the dock complete with road surfacing, bollards, sheds, &c. In the distance is seen the west quay, and to the right the north quay.

MAIN WHARF RECONSTRUCTION.

Whilst the wet dock, described in the preceding paragraphs, was being carried out, the reconstruction of the main wharf, lying to the westward of the dock, shown on the left-hand of the plan, Fig. 18, was also being proceeded with. Two types

of construction were adopted for this work, viz., concrete block-work and open wrought-iron cylinder work. The former type of construction was used for a length of 504 ft. at the western end of the work, where the shale, upon which the wall was carried, was found at a reasonable depth.

A section of this wall is shown on Fig. 31, Plate XLIX. The shale was excavated to the required depth, a foundation of concrete in mass being then deposited by special skips through the water and levelled off by divers. Upon this foundation the concrete blocks were laid, this work being brought up to a level slightly above L.W.O.S.T. The superstructure was then completed with moulded concrete ashlars backed up with mass concrete, similar to the work already described for the "Empire Dock" quays. The space at the back of the wall was filled up with selected filling, the quay surface and foundations for sheds being formed as already described. The wall was also provided with granite coping, fenders, bollards, ladders, &c. Eastward of the block-work wall, wrought-iron cylinder construction was adopted extending through the western side of the entrance into the wet dock. This type of construction was used because of the great depth at which the shale was found, rendering an ordinary block-work wall impracticable.

Typical sections of this work are shown on Figs. 29 and 30. It will be seen that it consisted of three rows of wrought-iron cylinders sunk through the mud until they reached a secure foundation, the sinking being effected by grabs worked by cranes from a staging. The cylinders were then filled with concrete and the space between them spanned by wrought-iron longitudinal and cross-girders, carrying a decking of corrugated steel troughing. The troughs were filled in with concrete, the surface being finally finished off with a granolithic coating. In conjunction with the cylinders a mound of granite rubble was deposited, surmounted by a dwarf wall of concrete blocks, as shown on the sections.

As soon as the Empire Dock had been completed and opened for traffic, the reconstruction of the main wharf to the eastward of the entrance was put in hand. This consisted of a block-work wall over a length of 2,640 ft., as shown in Fig. 18, the extreme eastern end being completed by reinforced concrete cylinder construction, on account of the depth of overlying mud.

Fig. 32, Plate XLIX, gives a typical section of the block-work wall, which is generally similar to that already described, except that, owing to its greater height, it is of heavier section and has been battered on the face.

Fig. 34 gives a plan and Fig. 36 a typical cross-section of the reinforced concrete wharf at the eastern end. Owing to the soft nature of the material over this portion of the work, it was not considered advisable to fill up the space at the back. Consequently, access from the quay to the sheds or godowns was given by means of the gangways shown upon the plan. The photographic views given on Fig. 38, page 669, and Fig. 39, page 682, show the wrought-iron cylinder work in the course of construction, while Fig. 40 shows the reinforced concrete cylinder work under construction, and Fig. 41, page 668, the work completed. The gangways and sheds are also clearly visible.

(To be continued.)

JAMES PRESCOTT JOULE, 1818–1889.

Beneath the memorials to Stokes, Adams, Lister, Wallace and Darwin in the "science corner" of Westminster Abbey, a plain white marble tablet perpetuates the memory of Joule and records the services he "rendered to science in establishing the law of the conservation of energy and determining the mechanical equivalent of heat." Close by, in the North Aisle, are the graves of Sir John Herschel, of Darwin and Lyell. In the Nave are also the graves of Telford, Stephenson and Kelvin, while the windows of the aisle bear the names of Trevethick, Brunel, Locke, Kelvin, Stephenson and Benjamin Baker. In this spot are thus commemorated some of the greatest men of science of the Victorian era, among whom Joule, by his masterly researches and philosophic insight takes a distinguished place. Though the new doctrine of energy took a quarter of a century to become universally accepted, its birth and development belong entirely to the reign of Victoria, and it was at the Queen's Jubilee in 1887 that Tyndall spoke of "the law of the conservation of energy which enables the eye of science to follow the flying shuttles of the universal power as it weaves what the earth spirit in Faust calls 'the living garment of God,' as the largest flower in the garland which the science of the last fifty years is able to offer to the Queen." Contemporary estimates of men and things are seldom wholly confirmed by succeeding generations, but there is as yet no difference of opinion on Kelvin's dictum that "Joule's discovery of the mechanical equivalent is the greatest reform physical science has experienced since the time of Newton."

Accounts of Joule's life and work have been contributed to the Proceedings of the Manchester Literary and Philosophical Society by Osborne Reynolds and to the "Dictionary of National Biography" by Glazebrook, and the main facts are well known. There is, however, so much of supreme interest in his early history of thermodynamics that, recollecting Pasteur's advice to the students of Edinburgh University, to "associate the cult of great men and great things with every thought," we have no hesitation in recalling again a few of the outstanding features of the remarkable epoch in which Joule is a central figure. The rise of thermodynamics is embraced in the decade 1840 to 1850. Before that period the old hypothesis of caloric had held a sway over the realm of physics as complete as the sway the phlogistic theory had once held in the field of chemistry. By 1850 nearly all the younger physicists had abandoned the idea of heat as a substance and had transferred their adherence to the new theory that heat was "a mode of motion" and this advance was due—at least in England—more to Joule than to any other man.

Prior to the time of Joule there had been the remarkable experiments of Davy on the friction of ice and Rumford's observations on the heat generated when boring cannon, resulting in his paper entitled "Inquiry Concerning the Source of the Heat Excited by Friction" (1798). Carnot's famous memoir "Reflexions sur la Puissance Motrice du Feu" appeared in 1824 and Clapeyron's essay "Sur la Theorie Mecanique de la Chaleur" ten years later. Mohr's "Ueber die Natur der Wärme" was published in 1837 and Seguin's "De l'Influence des Chemins de Fer" in 1839. All these writings contained the germs of the new doctrine, but they were only the preliminary skirmishes preceding the main attack. The first really decisive blow in the campaign was struck by the young German physician, Mayer, who from his obscure situation at Heilbron, launched, in 1842, his memoir, "Bemerkungen über die Kraft der unbelebten Natur," while the next two blows were delivered almost simultaneously by Joule and by Colding, the Danish civil engineer; by Joule in his paper on the "Calorific Effects of Magneto Electricity," which he read to "an unwilling audience of six" at the British Association at Cork in 1843; and by Colding in his essay of the same year to the Royal Society of Copenhagen, entitled "Theses concerning Forces," in which he explained the idea "that force is imperishable and immortal, and therefore when and where forces seem to vanish in performing certain mechanical, chemical or other work, the force then merely undergoes a transformation and reappears in a new form, but of the original amount as an active force." Joule's paper of '43 was followed by others in '45 and '47, at Cambridge and Oxford respectively, and finally by his memoir "On the Mechanical Equivalent of Heat" communicated to the Royal Society by Faraday, June 21, 1849. This was really the final action; the winning battle. It was in this paper Joule gave an account of his most refined investigations and for his previous values of the mechanical equivalent, viz., 838, 770, 798, 890 and 781—gave the value 772 ft.-lb. which was the recognised constant for half a century and differs little from that used to-day. Among other noteworthy contributors to the main question were Grove, who, in 1846, published his volume of lectures on the "Correlation of Physical Forces"; and Helmholtz, who, the following year, read to the Physical Society of Berlin his memoir "Die Erhaltung der Kraft." This was the essay which Magnus four years later put into the hands of Tyndall, remarking it was "the production of the first head in Europe since the time of Jacobi."

The controversy which arose over the respective merits of Mayer and Joule had its parallel in the contemporary controversy over the discovery of Neptune by Adams and Leverrier, and like that controversy had a more or less happy ending; the Royal Society awarding the Copley medal to Mayer in 1871. The fight for the new ideas had been by no means an easy one. Mayer's paper of 1842 was rejected by Poggendorf before being inserted in Liebig's "Annalen," and in 1844 one of Joule's memoirs was refused by the Royal Society. Of the state of scientific opinion of that time we are given a glimpse in Lyon Playfair's "Memoirs and Correspondence." "When Joule," wrote Playfair, "first sent an account of his experiments to the Royal Society the paper was referred, among others, to Wheatstone, who was my intimate personal friend. Wheatstone was an eminently fair man and a good judge, but the discovery did not then commend itself to his mind. For a whole Sunday afternoon we walked on Barnes Common discussing the experiments and their consequences, if true, to science, but all my arguments were insufficient to convince my friend, and I fear that then the Royal Society did not appreciate and publish the researches."

One of the results of Joule's paper of '47 was the lifelong friendship of Joule and Kelvin. Both Faraday and Kelvin—then Professor William Thomson—were present at the British Association meeting, and Kelvin afterwards confessed that "at first he thought Joule must be wrong, but as he listened he recognised Joule had certainly a great truth and a great discovery and a most important measurement to bring forward." On the subsequent development of thermodynamics by Kelvin, by Clausius and by Rankine—whose "Steam Engine" contained the first systematic treatise on the subject—or by Zeuner, Hirn, Tait and others, we cannot dwell. Joule for many years continued to add to his reputation, and he lived long enough to see his results confirmed and his views accepted. Born in Manchester on Christmas Eve, a century ago, he spent practically all his life in that city. As a boy he had the inestimable value of receiving instruction from the venerable Dalton, and on him Dalton's mantle fell. He was successively librarian, honorary secretary, vice-president and president of the Manchester Literary and Philosophical Society, and it was there throughout his life he found his most congenial associates. His name is perpetuated not only by the tablet in Westminster Abbey, but also by statues at Sale and at Manchester, and more than all by his imperishable record in the history of science "The philosopher," said Faraday, "should be a man willing to listen to any suggestion but determined to judge for himself. He should not be biassed by appearances; have no favourite hypothesis; be of no school and in doctrine have no master. He should not be a respecter of persons but of things. Truth should be his primary object. And if to these qualities be added industry he may indeed hope to walk within the veil of the temple of Nature." Joule, we feel, was a philosopher after Faraday's own heart.

COMPENSATION FOR INDUSTRIAL ACCIDENTS IN AMERICA.

Under recent legislation very considerable sums of money have been paid as compensation to workmen in cases of injury causing partial or total incapacity and to their representatives, where the accident has proved fatal. The amount so paid is known to officials with some degree of exactness, but the public know little of the effect produced on the recipients, or to what extent the humane purposes contemplated by such acts have been fulfilled. How do the families and dependents of the injured wage earners fare under the Workmen's Compensation Acts? Does the compensation received enable them to retain their physical and

moral health? Are homes broken up and the members submerged under the grinding, chronic poverty from which there is no escape, and do healthy lives become impossible? Is the compensation distributed in the most useful form, providing the maximum amount of assistance?

Official cognisance is concerned only in providing the mechanism of distribution. It cannot penetrate into the bereaved home and follow up the effect on the inmates. If such a searching inquiry is to be undertaken it must be conducted on practically private lines, and prompted by sympathetic individual motive. Miss Mary Conyngton, assisted by a competent staff and acting under the ægis of the United States Bureau of Labour, has made a very serious attempt to get below the level of official statistics and to study the effect in working men's families of these well-meant attempts to protect the victims of industrial accidents. The report* issued by the Bureau of Labour is interesting on several grounds, as we shall endeavour to point out, but it demonstrates the impossibility of obtaining statistics on a scale sufficiently wide to avoid the disturbing individual factors and to enable us to see the average conditions. It necessarily fails to provide a guide in great national emergencies such as this country must pass through in the next few years, while administering a pension system that is practically a form of industrial compensation.

Moreover, the issue in Miss Conyngton's report is confused by the introduction of another question, the relative merits of different systems of award to injured operatives. Each State can organise its own methods of compensation, or leave the measure of subsidy to individual initiative and determination. Two of the States selected for examination, Connecticut and Ohio, are each compensation States, the former having an elective compensation system, that compels any employer to insure his risks in a private company or to provide self-insurance. Ohio adopts a compulsory insurance method, requiring an insurance in the State fund, though employers may be permitted to carry their own risks. The third State, Pennsylvania, was selected by way of contrast, being a non-compensation State, but is under an employers' liability law. Only a portion of this State could be included, and the part selected was generally engaged in the mining industry.

The plan of examination involved visits to all families in which the head had been either killed, or had suffered permanent total disability during the year, ending September 1, 1915. Where the family had disappeared, or removed, the inquiry failed, and it is to be feared that the statistics refer more particularly to the provident class, who endeavoured to struggle against their misfortunes. From the three States, records were obtained of 862 fatalities and 15 cases of permanent total disability, of which total number, however, 68 did not come under the compensation laws. The number of families visited was only 487. The more destitute, it is suggested, escaped the inquisitorial net spread for them, making the general result more favourable than it should be. The object of the visit was to discover the condition of the family before and after the accident, the economic effect of the wage earner's death, or disability, the extent to which compensation had made up for lost earnings, and the method by which any deficit had been met.

For obvious reasons the whole of the 487 families did not submit information, or on various grounds, the information supplied was not material to the issue. The first table, interesting as showing the average wages earned in the United States, includes only 367 families, and where the number embraced in a particular class is only 18 or 10, percentages can be misleading. As we have said the number of instances is often not sufficient to support a plausible theory, though in some particulars, the inferences are eminently suggestive.

The average amount awarded as compensation was in Connecticut slightly over 7 dols., and in Ohio a little over 9 dols. per week, and the contribution was continued for a period of six years. In Pennsylvania, the State in which employers' liability laws were adopted, the families received an average dole of 66⅔ dols. in all. The low average received in Pennsylvania shows how far a voluntary system falls short of the need.

State.	Number of Families Reporting.	Average Weekly Family Income Before Accident	Average Weekly Family Income After Accident	Number of Families having no Income After Accident.	Number of Families having less than 5 Dols. Weekly.
		dols.	dols.	p.c.	p.c.
Connecticut	47	10·67	6·05	18=38.3	10=21.3
Ohio ..	198	19·46	5.42	65=32.8	51=25.8
Pennsylvania ..	122	20·43	6·33	32=26.2	35=28.7
Total ..	367	—	—	115=31.3	96=26.1

Voluntary insurance on the part of the wage earner is of little effect in securing an adequate provision for the family. The poorer wage earners have not the means to effect any insurance, and the better paid did not generally avail themselves of the opportunity. The amounts paid were too small to form any appreciable addition to the income if invested, or to provide for the daily necessities of the family for any length of time. The total average amount received in Connecticut was 588 dols., in Ohio 536 dols., and in Pennsylvania 736 dols., but these figures carry little weight, the numbers being so few, that an occasional large insurance influences the average very materially. As far as the figures go, there is slight evidence to show that some effort is made in Pennsylvania by the workman to supplement the inadequate award.

The extent to which distress was relieved in Connecticut and Ohio by the enforcement of the workers' compensation laws is marked and gratifying. The families of workers killed in industrial accidents were not found to any appreciable extent among those receiving charitable relief. The particular part of the economic loss involved in a wage-earner's death is not borne by the general public, but is shifted to the industry in which the fatality occurred. In the two States mentioned no family received less than 5 dols. a week, and only about one-sixth had less than 10 dols. The incomes are so much better than they would have been without compensation, that the situation seems relatively happy. One widow is reported to have found comfort in the well-meant remark: "Look how much better off you are than if he'd a died natural." The consolation might have been more tactfully administered or more gracefully expressed, but it was eminently practical and justified. By every test applied, it is safe to say that the compensation enables a thrifty, industrious family to adjust itself to the loss of its principal wage earner without appealing to public assistance or private charity.

In Pennsylvania, the conditions are more melancholy. The number of families who under normal circumstances received less than 10 dols. weekly income was only 1 per cent., after the accident the percentage who suffered from this exiguous wage, rose to 69. Before the decease, four-fifths of the families had incomes of 15 dols. or more a week; after the employer had compounded his liability, less than one-sixth were in this favoured group. It is to be feared that the actual conditions were worse than is shown by this calculation, for it necessarily leaves out of consideration the several cases in which, through poverty, the family ceased to exist as a distinct unit. The details that the visitors were able to collect show, that many families suffered miserably, a suffering that the voluntary action of the employers did little to mitigate. The comment made is quite justified, that, "as a whole the settlements made no pretence to adequacy, they were something and the families took them on the principle of half a loaf, but they bore no relation either to the needs of the survivors nor to the wage-earning power of the decedent."

One might anticipate that in States that accepted an Employers' Liability Law the families of injured operatives would find themselves at a disadvantage; there is no necessity to labour that point, but the extent to which the pecuniary claims on employers are avoided, could hardly have been foreseen. In Pennsylvania, nearly three-fifths of the families entitled to some compensation received absolutely nothing, and nearly four-fifths of those receiving a definite amount in settlement, were paid less than 1,000 dols. The possibility of an appeal to law, even in the worst cases, awakened no enthusiasm. It was felt that the power of the employers was too strong to be resisted. It were better to submit to injustice or lack of generosity than by opposing, make powerful enemies who could retaliate on other members of the deceased's family. But in Connecticut, where no legal expenses are necessary, the average total compensation amounts to 2,269 dols., and in Ohio to 3,098 dols. In Pennsylvania, on the other hand, in only five cases did the payment exceed 2,000 dols. Miss Conyngton sums up the case against Pennsylvania in the following terms: "Looking upon the situation in each State as a whole, that in Pennsylvania presented a nightmare of suffering and destitution, as compared with that in the other States. Neither of the compensation systems studied is beyond criticism, but their results are so superior to those of the liability system, that the claims of their advocates may be regarded as wholly justified." The heaviest part of the loss falls directly on the members of the families of the injured, and certainly not on the wealthy mining industry of Pennsylvania, on whose behalf the greater part of the injuries were sustained. Ultimately, the cost will be borne by the community at large. Few families looked for any prospect of improvement until the children were old enough to earn wages. But these same children were growing up under privations that entailed poor physique and lowered vitality. The community will have to pay in part for the up-rearing of those children under a crushing poverty; it will pay a heavier price in the injury done to the development of those children, from whom the workers of a few years hence must come.

The elimination of legal fees under the compensation laws to which brief reference has been made is an important point. Those fees can operate as a very heavy tax, and a class of lawyers exists for exploiting the opportunity. In Connecticut, where awards had been made in 70 cases, only one instance occurred in which legal advice had been necessary: the fee amounted to only 3·2 per cent. of the award. Where permanent incapacity followed or some uncertainty prevailed, appeals are more frequent, but these are rare and the expense is generally unwarranted. The fees occasionally amount to 30 per cent. of the total grant. In Ohio, nine cases came before the law courts and the costs occasionally amounted to 22 per cent. of the sum in dispute, but taking the total of 252 cases examined and compensated, the average legal expenses were under 10 dols. It may and does happen in either of these States that though an award is made, collection proves impossible. Employers, it is true, are bound either to insure or to satisfy the Commissioners of their ability to pay any award which may be rendered against them. Apparently, however, there is no efficient system of inspection to prove whether these requirements are carried out, and if the employer prove impecunious there is no remedy. "An award unenforced," says the report, is small comfort to a needy family, but there is no recourse. The decedent is in no way responsible for his employer's failure to comply with the law, yet his family must suffer for it." One valuable result of this report is to demonstrate that such instances of hardship are rare. A sufficient remedy would be to make the State responsible for the enforcement of its own laws, and in case of culpable evasion, the State should bear the cost of failure, not the dead man's family.

The methods adopted by the survivors to supplement the diminished income do not show any marked originality, from which useful lessons might be learned. To the credit of all concerned it should be said, that recourse to charity, public or private, was almost unknown. It might have been expected that children would have been withdrawn from school and put to work at an early age. That was an expedient to which few resorted. In Connecticut only four children, all over 14 years of age, were

* *Effect of Workmen's Compensation Laws in Diminishing the Necessity of Industrial Employment of Women and Children.* By MARY K. CONYNGTON. Workmen's Insurance and Compensation Series No. 11. Washington: Government Printing Office. [Price 15 cents.]

taken from school in consequence of their father's death. Some widows who had not worked outside the home sought profitable employment, but there were no cases in which children were neglected owing to the absence of the mother. In one case partially purchased property had to be abandoned but in three cases, mortgages had been paid off out of the compensation. In Ohio, the distribution of compensation worked equally satisfactorily. In very few cases was the family life broken up, and judged by the test of lost property in real estate, the results are even more gratifying. In 31 instances mortgages were cleared off property already owned, and none put on. No homes were lost through failure to meet payments as they came due. The plan of compensation, generously conceived and wisely administered, made it possible to keep a home together, to preserve the independence of the members, and to enable them to look hopefully forward to the better times to come, when the children would prove bread winners with promising chances of success.

WAR DEVELOPMENTS IN INDUSTRY.

Address by Mr. Kellaway.

Mr. Kellaway, Parliamentary and Financial Secretary to the Ministry of Munitions, delivered, in the last week of November, an address on "Some Developments in Industry During the War" before the Industrial Reconstruction Council. The following is a text of the address as reported in *The Board of Trade Journal*:—

In the early days of the Ministry I said that Mr. Lloyd George had gathered round him what might be described as a General Staff of British Industry. I hope I am not unduly exaggerating the part which the Ministry of Munitions has played in the development of our industries during the war, when I describe the building in which you are met (Hotel Metropole) as the general headquarters the British war industries.

I desire to speak this afternoon on some developments in industry during the war. It will, I am afraid, be necessary for me to make large demands on your patience; but the developments which have taken place have been so numerous and they are likely so profoundly to affect the future of British industry, that I hope you will feel that your time has not been wasted. In a recent speech Mr. Lloyd George said that the war had been like a star shell, illuminating the dark places in our national life. It would be equally true to say that the war has revealed with pitiless accuracy the defects in our industrial equipment. Many of these defects have already been overcome and, as a result of the war, the United Kingdom, whilst maintaining its position in departments of industry, where it has always held first place, is now first in the world in almost every sphere of industrial effort.

I shall deal first with developments in regard to raw materials, next with changes in the machine tool position, then with improvements in the shop method, which war experience has produced, and lastly shall show how we have made ourselves independent in a number of "key" industries which previous to the war were in the hands of our enemies.

Raw Materials: Mica.—The electrical industry has proved to be a great war industry. It is bound to become an even greater peace industry. Previous to the war Germany had established a predominant position in this industry; but this would not have been possible without the supplies of mica brought from India and other parts of the British Empire. Mica is absolutely essential to the electrical industry, and the position of the British Empire in regard to mica supplies was, and is, far and away the strongest of any country in the world. India produces 80 per cent. of the world's supply of mica, and Canada 15 per cent. Germany within her own Empire obtains 10 per cent. of the world's supply, this being found in German East Africa. But in spite of the overwhelming national advantages of our position at the outbreak of war, the mica market of the world was at the point of being transferred from London to Hamburg, thanks to the skill with which Germany had obtained a large measure of control of the Indian mines, and the success with which she had captured the electrical industry. The Indian mica was either exported direct to Germany (she took 47,000 cwt. in 1913) or was re-exported from this country to Germany, 80 per cent. of our total imports from India in that year being so re-exported. When war broke out we stopped Germany's supplies from India and from German East Africa. Germany then tried to form a combine in a neutral country to impede production. To some extent she was successful, and it took some time before the Indian mines recovered. I need not detail the measures by which the situation has been restored. Sufficient to say that the Indian mica can now be exported to London only, and that the mica in German East Africa is now being worked for and obtained by the Ministry of Munitions. We take the necessary steps to see that Germany gets none of it. Thanks to these measures and to the necessities of war, the British electrical industry has taken the place previously held by Germany and Austria, and is now the first in the world. The demands for mica for the electrical industry are bound to increase, and the expected developments of commercial aircraft, wireless and motor traction, make it essential that the Empire's supplies of this vital raw material should be safeguarded. The electrical industry is bound to be of such importance to the future industrial development of this country that we cannot afford to take risks with the valuable raw material of mica, with which the Empire has been so bountifully endowed.

Tungsten.—Tungsten is essential to the manufacture of high-speed steel, and high-speed steel is a vital war material. Tungsten is also used in the manufacture of metallic filaments for electric lamps and in certain appliances for wireless and other electric uses, where to some extent it has taken the place of platinum. But its principal use is in the production of high-speed steel. Before the war the British Empire produced 40 per cent. of the wolfram ore from which tungsten is made, but so successfully had Germany captured the trade that no British manufacturer was able to establish the industry in this country. At the outbreak of war one of the two firms endeavouring to manufacture in this country was only able to keep going with difficulty, and the other only succeeded in keeping its works going by entering into a contract to supply the whole of its output to Messrs. Krupp, of Essen. Germany owed her greater superiority in munitions production in the earlier stages of the war to the success with which she had captured the industry of tungsten production. All that has been changed. We are now able to produce all the high-speed steel needed for our own industries and to export at a reasonable price to our Allies. British manufacturers are now in a position to deal with all the British Empire production of ore and could, if necessary, convert the whole world's output into tungsten metal or ferro-tungsten.

Ferro-Chrome.—Ferro-chrome is an essential material in the production of certain classes of steel. Alloyed with steel it acts as a toughener and is used as chrome steel for armour-piercing shells, in armour plate, for the wearing parts of aeroplane engines, and gears in motor vehicles. For peace purposes it will be largely employed for such various purposes as motor parts, stainless cutlery and rustless steel. Before the war the United Kingdom production was practically negligible. We have now established at Newcastle-on-Tyne a plant sufficient to meet our requirements for many years to come. Previously we imported our supplies from Norway, where it was produced by hydro-electric power. At Newcastle the power is obtained from the waste gases from coke-ovens, and the industry will be in the unique position of competing successfully with the cheap water power of Scandinavia.

Spelter.—Spelter—or zinc to give it its correct name—occupies the third place in point of importance amongst non-ferrous base metal. The world's consumption in 1913 was 1,012,000 tons, as compared with copper 1,044,000 tons and lead 1,196,000 tons. It is an essential material in industry in the making of a large number of domestic articles and in building construction. Its main uses are for galvanising or coating iron and steel, to prevent rusting, and for mixing with other metals to form brass gun-metals and other alloys. It is also rolled into sheets for roofing and electrical purposes. The oxide of zinc forms, next to white lead, the most important pigment. It is an indispensible compound of manufactured rubber, and it is used extensively for medicinal purposes. The British Empire is fortunate in possessing in Australia practically unlimited supplies of zinc ore (concentrates), these being amongst the largest in the world. For reasons which it is not my present duty to examine, Germany obtained control of these important ore supplies. She imported from Australia a large portion of her supplies of zinc ore, and on these was able to extend her important zinc industries. Our own position, previous to the war, was that we used annually 240,000 tons of spelter in various forms, of which 77 per cent. was imported. Practically all from Germany, Belgium and Holland; Germany being the largest exporter to this country, sending us in 1913 1,500,000*l.* worth of spelter, besides smaller values of sheet zinc, zinc oxide and lithopone. At the outbreak of war these supplies ceased, and we were faced at the same time with a tremendously increased demand for spelter to be used in the making of brass for fuses, cartridge metal and so on. Our immediate needs were principally met by imports from North America. The price bounded up from 23*l.* per ton to 120*l.* per ton. This figure led the U.S.A. smelters to erect new works, and by the middle of 1917 the price had come down to 50*l.* The need for war purposes was thus met. But it was obviously dangerous to have to depend on outside sources to so great an extent for what was an essential material for war as well as peace. The first step taken was to divert the stream of zinc concentrates which had flowed from Australia to Germany, and make them flow from Australia to this country. That has been done. These essential raw materials have been diverted—permanently I believe—to this country. The raw material having been secured, steps were taken to increase the plant available for smelting the ore into metal and for the manufacture of zinc sheets, and the zinc smelters in this country were got together, and arrangements made whereby these plants were doubled, and in some cases trebled. Unfortunately, before these extensions were completed the shipping position from Australia became so serious that all shipments of zinc ore from that quarter had to cease. But that difficulty should soon disappear, and with the ore coming in freely, and labour and coal available for working the increased plants, the home production of spelter should reach 140,000 tons per annum, as against 32,000 tons before the war. The production of zinc oxide has also been encouraged, and on a war basis we are self-supporting, and there is no reason why we should not be self-supporting on a peace basis.

Potash.—Potash is essential for fertilisers and in certain industries, particularly dyes, drugs and glass production. There are no known natural deposits in this country. Germany possesses large natural deposits, and we depended for our pre-war supplies of 30,000 tons per annum entirely on potash brought in from the Strassfurt Mines. The war put an end to this source of supply, and it became necessary to find alternative sources. Investigation revealed the fact that 50,000 tons of potash was going to waste every year, in the dust or fume from blast-furnace gases. The problem of collecting these dusts was a difficult one. The only known method was the Halberg-Beth system—a German invention. This was complicated and required a large amount of steel and labour. The design has been modified to ensure greater reliability, lower capital cost and a small quantity of steel. Plants in hand, and those in course of erection without these modifications, should produce 18,000 tons of potash per annum. In addition, the Ministry has initiated an entirely new method of gas cleaning for the collection of potash-bearing dust from blast-furnace gases. Two large-sized plants are being erected at two blast-furnace works, which should produce about 1,600 tons per annum. It is confidently hoped that when these are working, similar plants will be extensively installed, and a considerable increase in potash production obtained. Other sources of potash from what is now waste material in cement kiln gases and suint liquors—the liquors derived from washing raw wool—are being investigated. Whilst it is too soon to say definitely that we shall become entirely independent of outside supplies, we are a long way on the road. Given labour, material and wisdom, we ought to reach the goal of complete independence in a comparatively short time. Germany had relied on her practical monopoly in Europe of natural deposits of potash to enable her to bargain for the recovery of her world market. She will be disappointed. British enterprise and judicious Government assistance have taken that power from her.

This is a particularly gratifying example of industrial development. The extraction of the flue dust will not only provide an invaluable supply of potash, but the process of cleaning the flue gases makes the gas available as a source of power. If there were no question of utilising the dust for potash, it would still be worth the while of blast-furnace proprietors to instal cleaning plants for this purpose alone.

Machine Tools.—After the material comes the machine tools used in working the material. This was one of the industries that presented us with what looked like an almost insoluble problem at the beginning of the war. I well remember the days when Mr. Lloyd George called the machine tool makers of the country together at Whitehall Gardens, put the position to them, and said that he relied on them and on their employees to help the country out of the difficulty with which it was faced. The position has been met with astonishing success, having regard to the difficulties which the manufacturers have experienced in obtaining the necessary amount of skilled labour. Whilst we have never had as many machine tools as could have been utilised, and it has been necessary to put severe restrictions on the use of machine tools for other than munition purposes, our munitions supply have never been jeopardised by the lack of tools. The output in this country before the war was valued at 4,000,000*l.* per annum. For the year 1917 the output was increased to approximately 6,500,000*l.* per annum, based upon pre-war prices. At war prices the actual output value was approximately 10,000,000*l.* Before the war we relied to a very large extent upon American manufacturers for the supply of high-class precision and automatic machinery. Thanks to the experience gained during the war the trade is in a far better position to supply the demands for this class of machinery. The increased war output has been reached by concentrating manufacture upon the production of a limited number of types. The economy consequent upon the specialisation has been so fully demonstrated that it is highly probable the manufacturers will continue to specialise. Our position as compared with Germany has been immensely strengthened. After making due allowance for the inflation of prices, the actual output of British machines shows an increase of 65 per cent. in 1917 over pre-war production, as compared with the German, increase of 23 per cent. There is no reason why British manufacturers should not make this country entirely independent of outside supplies of machine tools.

Improvements in Engineering Methods.—One of the greatest advances made has been the vast improvement in the machinery, accuracy of work, and in efficiency which is the result of the necessity of organising for the production of interchangeable repetition work. In many shops the apparently fine limits which war work required caused considerable dismay at the start, and one old foreman, who has since made good in every way, explained in distress: "We never worked nearer than a sixty-fourth before the war, and now we are asked to work within one-thousandth." Many old machines were found to be entirely unsuitable for giving the accuracy which interchangeability necessitates, and fresh machines have been necessary. When these have been put down they have naturally been more up-to-date, and in every way more efficient. A good deal could be said on the increased efficiency of our production, effected by the increased use of thread milling machines, improvements in screw threads, development in drop stampings, increased use and delicacy of gauges, die castings, but these are all questions rather for the engineer, and I must pass them by.

All this has led to a realisation of the importance of having a good and up-to-date tool-room attached to every shop of importance. Here the necessary tools are manufactured by men who are expert in this particular work, and the matter not left to haphazard manufacture in the shop itself. This was previously appreciated by up-to-date firms, but owing to the demands which the war has created, it has become the first essential in every shop of any size. Here, again, the importance

which was realised by only a few progressive firms of the use of "jigs," by means of which machine operations can be carried out rapidly and with every accuracy is now recognised practically universally. This allows of much greater efficiency in the shop, as the work can be fixed in the desired position at once on the machine, and the operator is saved the time spent in setting it.

One of the small ways in which very great advance has been made is in shop transport. Not only have mechanical conveyors been utilised to an extent never dreamt of, but many other means have been employed, of which two are now of universal application. The first of these is the electric truck, which, with or without trailers, is employed for carting work about the shop. The first one ever used in England was only brought over from the United States of America about seven or eight years ago, whereas there is now no shop of any size which does not employ this ready means of transferring material. The other means of shop transport which has come in is the small platform or skid, which appears to have runners on it like a sledge. In the hollow space between these runners a very low truck on wheels can be inserted, and by movement of a lever lift the skid, run it to the desired position, and deposit it with its load of work exactly where it is required, going back to deal with the next.

Scientific Knowledge in the Shops.—Nothing is more marked in the progress which shop engineering has made than the sweeping away of the old idea that scientific knowledge was very useful in the laboratory, but impracticable in the shops. It is now realised more than ever it was before, or than it would have been for years to come had it not been for the necessities arising out of the war, that science is the handmaid of production. There is hardly any point that you can touch in the manufacture of munitions where scientific knowledge has not been of the greatest importance to production. A quite small example of this will help to make the point clear. A shop manager in August, 1914, had undertaken the manufacture of a certain article of non-ferrous metal, but although he was able to meet in the foundry the specification required, he found that the work was taking, owing to the hard nature of the metal, too long in the machine shop, and that he either had to shorten the time of the operation or to get more machines, at that time practically unobtainable. Fortunately, he had enough metallurgical knowledge to realise that something might be done, even on what at first sight seemed to be a difficult problem, namely, to obtain greater ease in cutting without at the same time losing the properties of the metal which allowed it to satisfy the Government tests. Placing the matter in the hands of the works' metallurgist, in a week's time the machining time of the article had been halved, and the supply of the requisite number of the essential article assured.

Another instance, on a much larger scale, is the study which has been made of alloy steels, giving as they do such high strengths as have allowed of their employment for aeronautical purposes, thus lightening the aeroplanes and allowing of better performance. The same holds to a certain extent with the light alloys employed for aircraft work, giving much greater strength than formerly and allowing of lighter sections being used.

Weight of Aircraft Engines.—Amongst the advances which have been made in this war, none can be compared with that made on aeronautical work. This opens out so wide a prospect that I cannot deal with it now. But I must refer to the sensational advance which has taken place in aircraft engines. These not only have become more powerful, but their weight for 1 h.p. has decreased to about one-third of what it was at the beginning of the war, and it is not too much to hope that before long the power of the engine in horse-power will be the same as its weight in pounds, *i.e.*, 1 lb. per horse-power.

Magnetos.—Modern warfare, and a great part of modern transport and of modern industry, depends on the magneto. In the air it is an essential source of power and movement. The position of this country in 1914, in regard to the production of magnetos, was very grave. Only one firm—Messrs. Thomson Bennett Magnetos, Limited, of Birmingham—was producing magnetos. Their output for 1913–14 was 1,140 magnetos of a simple type. The Admiralty and the War Office endeavoured to meet our war requirements by importation, but by July, 1915, it had become evident that if we continued to depend on imported magnetos our war effort would be terribly hampered. The Admiralty then undertook to foster the supply of home-produced magnetos for all the fighting services, and continued this work until it was taken over by the Ministry of Munitions in April, 1917. The problems to be overcome were many and difficult. Suitable magnets were not obtainable in the British Isles, or the necessary hard rubber insulating material, or fine copper enamelled wire, or oiled silk or paper for insulation. For the best quality enamelled wire we have still to depend to some extent on the United States of America and for oiled silk on Japanese fabric. But the progress made in providing these four essential materials at home has been wonderful. If we are not yet entirely self-supporting, we soon should be. Of the technical problems I am not competent to speak, but I can only say that they have been solved in a way which does the greatest credit to the manufacturers and to the officials of the Admiralty and Ministry of Munitions. I shall mention very few names, for there are so many deserving honour, but I cannot forbear expressing the obligation the country is under the Mr. Peter F. Bennett, of Messrs. Thomson Bennett Magnetos, Limited. Mr. Bennett is chairman of the British Ignition Association, and was chairman of its predecessor, British Aero-Magneto Manufacturers. Thanks to a display of grit in the face of almost insuperable difficulties, of resource and of patriotism, as fine in its way as that shown by our fighting forces, the British magneto position has been established, and I think, made unassailable. Instead of one firm producing only 1,140 magnetos in a year, as was the case in 1914, we now have some 14 firms producing 128,637 magnetos in a year. The monthly output at the beginning of the war was 100. The output for October of this year, 18,000—that being the largest, figure yet reached—It is not only that we are producing in quantity which makes us independent of outside sources; the quality of the British magneto is the highest in the world. It is lighter in weight and more reliable in service than the Bosch magnetos manufactured before the war, or than the latest examples found in captured German aeroplanes. It is not only on the field that we have beaten the Bosch.

I can best illustrate the improved position by recalling an incident in the history of one of the scout aeroplanes which did much to make us supreme in the air. When its trials were to begin, the engine would not start owing to magneto trouble. An old Bosch magneto was begged or borrowed from somewhere, and was substituted for the British magneto attached to the engine, with the result that the engine started up without any trouble. We have changed all that now.

Ignition Plugs.—The ignition plug ranks with the magneto in importance and it presented similar difficulties The pre-war output of this country was insignificant. There were three firms manufacturing, and their total output for all purposes during 1914 was not more than 5,000. To-day five firms in the country are producing mica plugs, and their output for the year ending October 31 last was 2,148,726. The October output was 303,449, as compared with a monthiy output of 420 in 1914. It is gratifying to be able to state that the French, Italian and American services endeavoured to obtain British plugs. But there is room for further improvement in the design of mica sparking plugs for aircraft work. I think we can safely rely on our manufacturers not to rest and be thankful, but to make the British plug not only the best in the world—it is that already—but the best that science and mechanical skill can make.

Scientific and Optical Glass.—This country very nearly lost the war owing to the fact that it was almost entirely dependent on Germany and Austria for scientific and optical glass, and to the backwardness of our glass industry taken as a whole. There were a few refreshing exceptions—firms which had kept the flag flying—but generally it is true to say that we were dependent on Germany and Austria for supplies essential to success in war, and for a wide range of peace purposes. The glass industry is exceedingly complex. It includes in its scope articles so varied as X-ray tubes and beer bottles, glass eyes and lamp glasses, jam jars and thermometers.

Before the war the optical and scientific instrument industry in this country was in a lamentable condition, the trade practically having degenerated into a collection of middlemen, who mainly sold instruments completely manufactured in foreign countries, or bought in foreign parts and assembled them in this country. All that has been swept away by the bitter necessities of war. Our output has increased at least 20 times, and we are now self-supporting. Our pre-war output of optical glass amounted to about 10 per cent. of our peace requirements, the balance coming principally as to 60 per cent. from Germany and Austria, and 30 per cent. from France. Our output has developed to such an extent that it is now in excess of that which can be absorbed by this country, even under the most favourable conditions in peace time, and we must look to the development of foreign markets, which previously were the monopoly of Zeiss or Zena, for disposing of the balance of our home-produced supplies.

Scientific glass ware can be divided into furnace-made and lamp-blown. Almost without exception the furnace-made scientific glass ware used in this country was, before the war, obtained from Germany and Austria. As regards lamp-blown scientific glass ware, there existed a few small firms capable of executing repairs and making a limited number of articles of special design. Beyond this, our requirements were met by supplies which originated in Austria and Germany. To show the developments made during the war, it is sufficient to state that starting at practically nothing, the turnover of the scientific glass ware industry is now equal to more than 600,000*l.* per annum. Within a short period, by careful and judicious treatment, this country should be independent of outside supplies.

Before the war, the whole of the glasses for miners' safety lamps and oil lamp chimneys were obtained from abroad, mainly from Germany and Austria. Seventy-five per cent. of the glass bulbs, tubing and rod for electric lamps also came from Germany and Austria. Our dependence on Germany and Austria for the glass for our miners' safety lamps very nearly landed us in disaster. The position was so serious that the Home Office was bound to relax the very stringent conditions, which up to that time had been insisted upon, with regard to the quality and dimensions of glasses for miners' safety lamps. It was a serious thing to do, but there was no alternative, as it was impossible to obtain supplies of the necessary quality. The Home Office came to the Ministry of Munitions for assistance, and notwithstanding the extraordinary difficulties met with we are nqw producing sufficient supplies of the right quality. The situation is so easy that it is proposed to prohibit, as from March 31 next, the use of unapproved glasses. This country's output is alone sufficient to meet all our requirements. As regards oil-lamp chimneys before the war, practically none were made in this country. The position has been greatly improved, but there is room for greater improvements. Then take the position of glass used in the manufacture of electric lamps. Before the war our output of bulbs for this purpose was approximately 12,000,000 per annum, and three out of every four electric light bulbs in use in this country were imported, principally from Germany and Austria. We are now manufacturing sufficient to meet our essential needs.

Dial Sights.—It is a humiliating admission to have to make, but it is the fact that at the outbreak of war a considerable part of our artillery was equipped with gun sights exclusively manufactured in Germany. The sight is known as Dial Sight No. 7, and was patented by C. P. Goers, of Berlin, both in Germany and this country. At the outbreak of war, the War Office had already approached the British manufacturers—Messrs. Ross, of Clapham Common, and Messrs. Beck, of Kentish Town—but the position as regards these sights was exceedingly serious when the Ministry of Munitions was formed. The total deliveries to October, 1915, were 1,362. The total deliveries to date entirely from home manufacturers are 21,000. The two firms I have mentioned were recently producing 250 per week. The sight is a beautiful and delicate piece of work, and its production in such numbers, and in a perfection which Germany never exceeded, is a triumph for British skill. It is at any rate a comfort to know that we no longer have to depend on potential enemies for the sighting of our magnificent artillery.

Domestic Glass.—Then we come to the glass for domestic use, bottles and jars used as containers for food-stuffs and for preserving. Our production in 1914 for vacuum fruit jars alone was 22,317 dozen. In 1918 it was 83,333 dozen. We are now quite self-supporting. Much more remains to be done by the provision of more efficient works and furnaces, the installation of the most modern machinery, the development of potash production, the training of labour, scientific research and Government organisation. The trade will, I know, recognise how much the industry has been assisted by the Ministry's glass organisation, under the late Mr. A. S. Eaglemont, C.B.E. (whose recent death was a great loss) and, since his death, under Mr. Arthur Colefax, K.C.

THE COAL SHORTAGE.—The Coal Controller issues the following figures which show a further serious falling-off in the estimated output of coal during the first 40 weeks of this year compared with the output during the corresponding period of last year. The net shortage is nearly 16,500,000 tons, or about 8·4 per cent. Although miners will shortly be returning to the mines at the rate of 5,000 a day, there is a large leeway to be made up and some little time must elapse before the increase in the output of coal is felt :—

Period.	Output of Coal. 1918. Tons	1917. Tons
First four weeks ended February 2, 1918 ..	18,826,700	20,430,600
Second four weeks ended March 2, 1918 ..	19,141,600	19,881,500
Third four weeks ended March 30, 1918 ..	18,759,700	19,840,400
Fourth four weeks ended April 27, 1918 ..	17,698,400	18,659,200
Fifth four weeks ended May 25, 1918.. ..	16,856,800	20,092,600
Sixth four weeks ended June 22, 1918 ..	17,791,800	18,727,300
Seventh four weeks ended July 20, 1918 ..	15,780,300	18,982,800
Eighth four weeks ended August 17, 1918 ..	16,042,200	17,760,200
Ninth four weeks ended September 14, 1918 ..	17,767,000	19,502,600
Tenth four weeks ended October 12, 1918 ..	17,890,300*	19,159,100
	176,554,800	193,045,300
		176,554,800
Deficiency		16,490,500

* Provisional.

It will be observed that for the four weeks ended October 12 it is estimated that 17,890,300 tons of coal were raised at mines in the United Kingdom, as against 19,159,100 tons during the corresponding period of 1917 —a shortage of 1,268,800 tons. The chief disturbance during the period was due to the railwaymen's dispute, owing to which one day on the average was lost by the pits in South Wales and Monmouth. Making the best practical estimate for the loss of time in each of these periods due to holidays, disputes, accidents, &c., the capacity of the industry during the four weeks ended October 12 this year was about 11 per cent., or nearly 574,000 tons per week, less than in October, 1917. As compared with the previous four weeks ended September, 1918, there was an increase of less than 1 per cent. in the capacity of the industry. Since the end of last March the stocks of coal held at the mines and in trucks has been reduced to the extent of approximately 1,000,000 tons. Improvements were again shown in the last four weeks of the table in the number of days worked by miners in the following counties compared with last year :—

	Days per Week.		Days per Week.
Worcester ..	0·81	Fife and Kinross	0·62
Monmouth ..	0·74	Glamorgan ..	0·49
Haddington ..	0·70	Stafford South..	0·48
Pembroke ..	0·70	Edinburgh ..	0·44

CHRISTMAS DELIVERIES BY MOTOR.—The President of the Board of Trade, having considered the representations of the Commercial Motor Users' Association, the Petrol Controller has arranged forthwith "to consider on its merits any individual application for an increased allotment, in view of the additional quantity of food-stuffs to be delivered during December." Captain F. G. Bristow, the General Secretary of the Association, 83, Pall Mall, S.W. 1, will be glad to assist traders using commercial motors for the distribution of food-stuffs, who desire to make special claims.

LAND AND MARINE STEAM TURBINES.

CONSTRUCTED BY THE ATLAS ENGINEERING COMPANY, COPENHAGEN.

(*For Description, see opposite Page*)

Fig. 1.

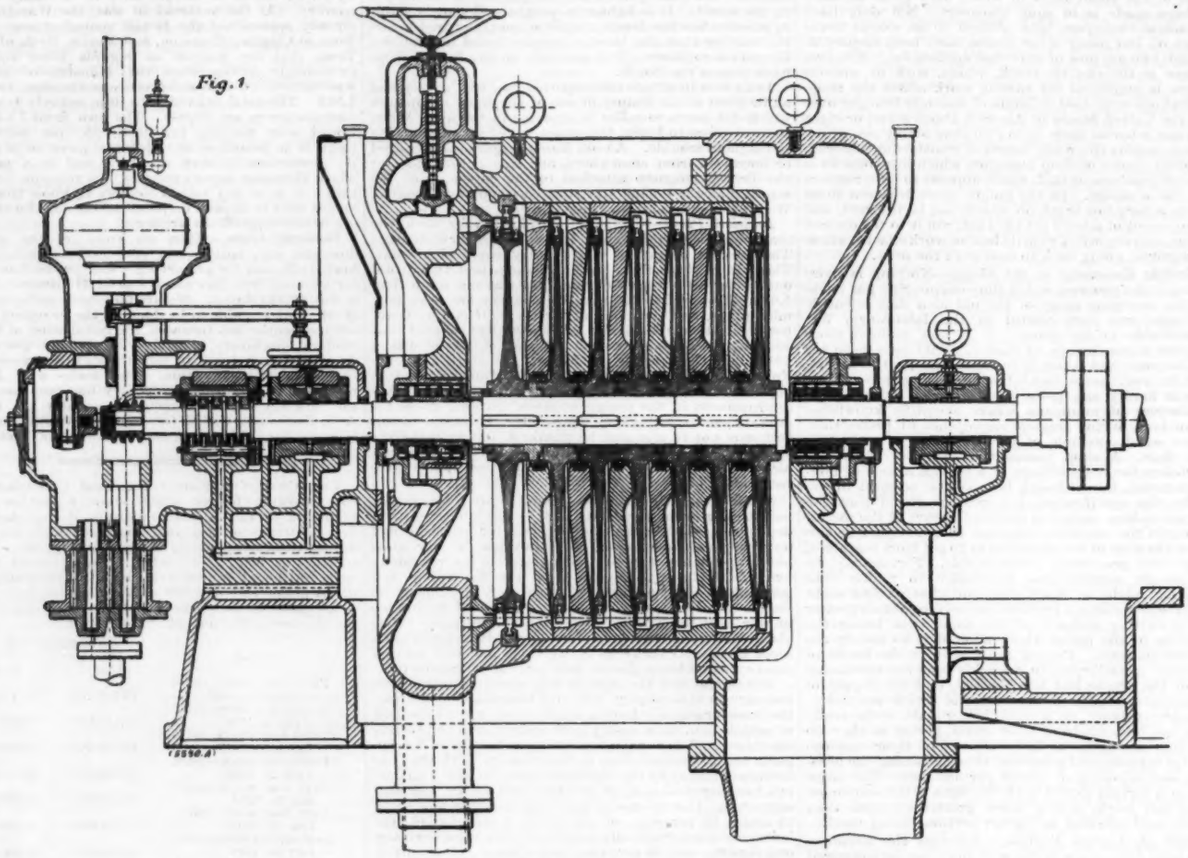
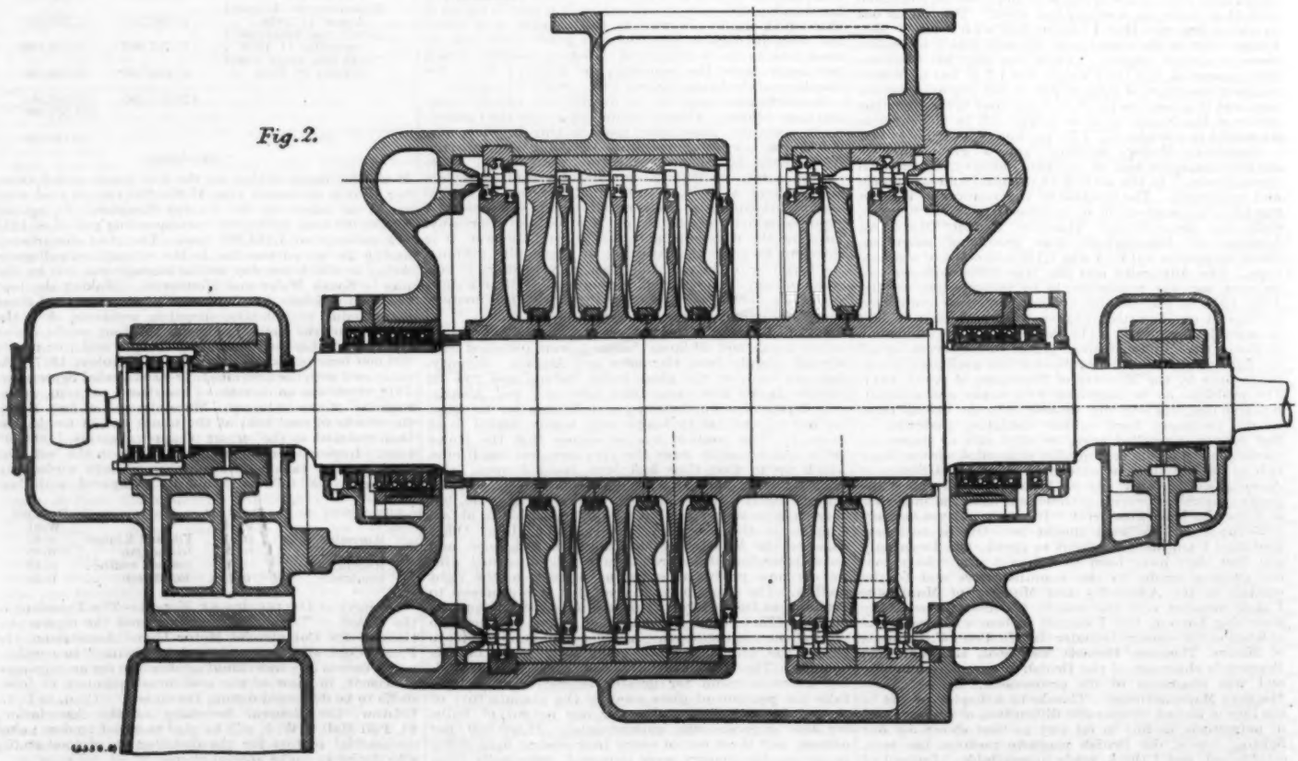


Fig. 2.



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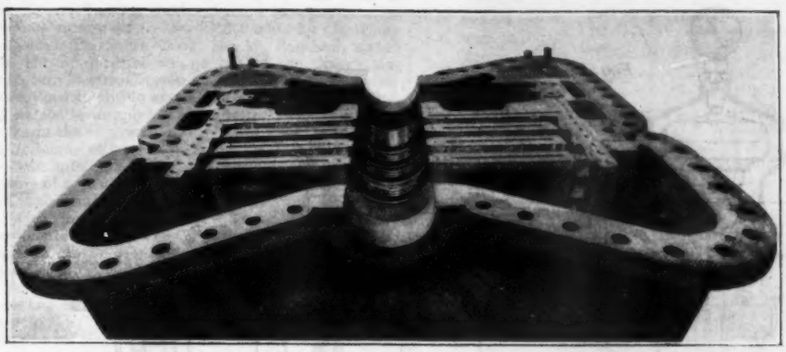


FIG. 3.

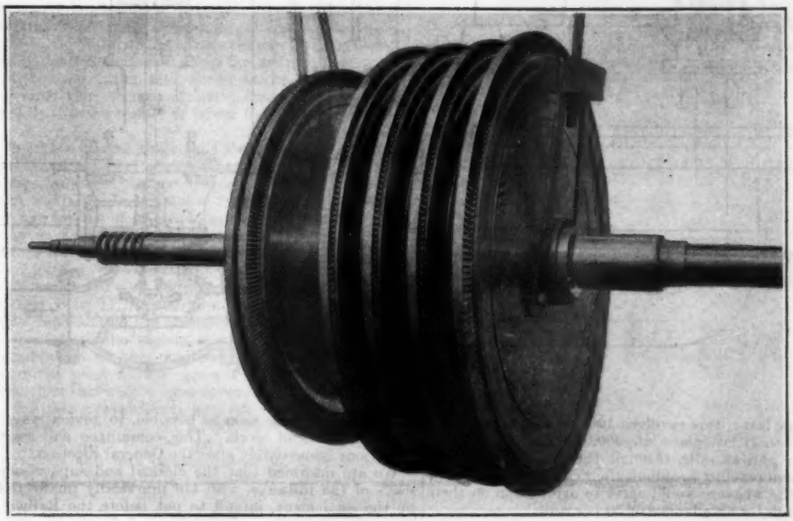
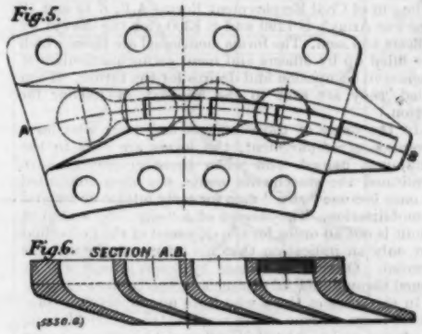
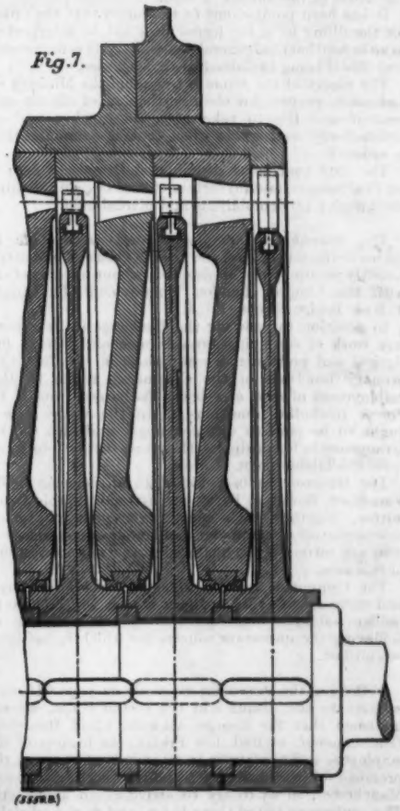
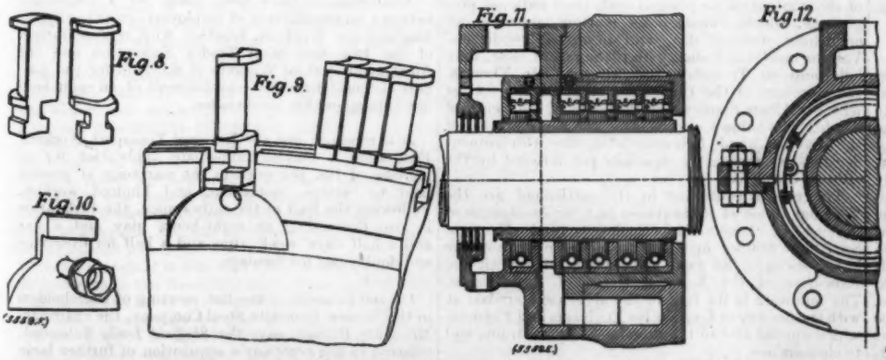


FIG. 4.







We illustrate on the present and opposite pages a land and a marine turbine constructed by the Atlas Engineering Company, of Copenhagen. This firm up till recently built reciprocating engines only. In deciding to embark on turbine building, it was determined to avoid the introduction of untried novelties and, as will be seen, the turbines are constructed on familiar lines embodying no untested features. The main interest of the machines lies in the fact that they have been produced without it being thought necessary to pay large sums for the benefit of other firms' experience. The land pattern is illustrated in Fig. 1, whilst Fig. 2 represents the firm's geared marine type. As will be seen, both are familiar patterns, being straightforward impulse turbines, with one velocity compounded stage for the land turbine and for the ahead portion of the marine turbine, whilst the astern portion of the latter has two velocity compounded stages and is capable of developing 85 per cent. of the full power ahead. The diaphragms are of cast-iron. The guide blades are of steel and are cast on. As shown in Fig. 3 these diaphragms are split along a horizontal joint, a practice now universal, as the one-piece diaphragm, at one time experimented with, though mechanically sound was frequently found to give rise to trouble when repairs were necessary. The rotor lifted clear of its bearings is represented in Fig. 4.

The steam supply to the first stage is taken through a nozzle-box as usual, and to this nozzle-box high temperatures and pressures are thus confined. This nozzle casting is represented in Figs. 5 and 6.

The wheels are steel forgings, having the section indicated in Fig. 7. The blades are cut from the solid, and, as shown in Figs. 8 and 9, are of the pattern originally introduced by the British Westinghouse Company, in which the shrouding is in one piece with the blade. The blades are assembled in their groove through a "light" cut for the purpose, as indicated in Fig. 9, the stopper piece for which is represented in Fig. 10. The glands (Figs. 11 and 12) are of carbon, and the system of spring balancing them from below adopted by many firms has been dispensed with.

The arrangement of the valves, governor and oil pumps is illustrated in Fig. 13, on page 676, and follows familiar lines. The governor valve, which is of the balanced double-beat type, is moved to suit the load by means of an oil-operated servo-motor, the valves of which are controlled by the governor. The usual overtaking gear is provided to prevent hunting. The emergency governor is of the sliding pin type and can be seen to the left in Fig. 1. In the case of a runaway it trips the stop valve, which then closes automatically under the action of the spring shown in Fig. 13. As usual, provision is also made enabling this valve to be tripped by hand. It is common practice to shut down the turbine by the use of this hand operated trip gear, as the plan ensures that the emergency gear is maintained in working order. Both turbines, it will be seen, have old-type thrust blocks, the Michell pattern having not yet been adopted by the builder.

INDUSTRIAL NOTES.

The following announcement is issued by the Department of Demobilisation and Resettlement of the Ministry of Labour.

The Admiralty, the Army Council and the Air Ministry have issued special instructions with regard to the filling in of Civil Employment Forms A.F. Z 15 and 16 (for the Army), S 1299 and S 1300 (for the Navy) by officers and men. The forms mentioned are those which are filled up by officers and men, giving particulars of their civil occupation and desires for the future. When filled, they are sent to the Ministry of Labour for action.

In the cases of those officers and men who have promises of employment, the forms are sent to the employers named, and when those employers have confirmed the statements made, the men concerned at once become "slip" men for early release on general demobilisation. The receipt of a "slip" by a ship or a unit is not an order for the dispersal of the individual but only an indication that his future employment is assured. Orders for release by trade groups will be issued through official channels in due course.

In the cases of those who have no employment promised them, or who desire training, the particulars on the forms will assist the Ministry of Labour in meeting the needs of the officers or men.

It has been pointed out to the forces that the order for the filling in of the forms must not be interpreted as an indication that general demobilisation is imminent, and this is being explained to all concerned.

The object of the forms is to enable the Ministry of Labour to prepare for the resettlement of officers and men in civil life to take place as quickly and as satisfactorily as possible when general demobilisation is ordered.

The only men being demobilised at present are :—(*a*) Coal-miners, and (*b*) certain classes of men for shipyard work ; (*c*) demobilisers and pivotal men.

The attention of employers and workpeople is drawn to the activities of the Local Advisory Committee recently set up by the Minister of Labour in connection with the City of London Employment Exchange, 9, New Bridge Street, E.C.4.

In addition to assisting the Exchange in its extensive work of supplying suitable men and women for clerical and professional occupations in the City, the primary functions of the Committee relate to the employment of men now being discharged from H.M. Forces (including questions as to the wages which ought to be paid to disabled men), and also to the arrangements for dealing with reconstruction problems from the labour point of view.

The Minister has been fortunate in securing Sir T. Vansittart Bowater, Bart., as chairman of this Committee, together with many prominent citizens—representative of employers and labour organisations—who are intimately acquainted with trade conditions in this area.

The Committee has already held several meetings, and there seems every prospect that it will be able to render valuable assistance to the Government in achieving the important objects for which it has been established.

Following the statement we made on page 641 *ante*, relative to the disquiet in the cotton trade, we are informed that Sir George Askwith, Chief Industrial Commissioner, invited, last Friday, the leaders of the employers and operatives to meet in conference at the premises of the British Cotton-growing Association, Manchester, so as to try to arrive at an agreement. The conference lasted three hours, and it was officially stated afterwards that no agreement had been reached. Mr. Pogson, the Federation secretary, said that the proposal by the employers was as follows :—"In view of the fact that the situation in the trade has changed very unfavourably for the employers since November 1, when their offer of a 40 per cent. advance on standard list wages, together with other conditions, was made, the employers, although of opinion that they would be entitled on the present state of trade to reduce that offer, are willing, in order to arrive at a settlement, to allow the offer of 40 per cent. on list rates for six months, together with the conditions attached thereto, to remain open for acceptance to-day. Failing the acceptance of this offer, it is hereby withdrawn, but the employers are willing that the matter in dispute should be settled by arbitration."

To this, the operatives replied :—"We cannot agree to accept your offer made on November 1, and repeated to-day, and in view of our past experience we cannot agree to arbitration."

It is stated that the operatives directly concerned in the strike number about 50,000 spinners and 50,000 card-room workers. As many as 250,000 weavers will be involved, since the stoppage of the spinning mills will bring about the closing of the weaving sheds.

The strike of the cotton spinners, commenced on Saturday last ; this involves 100,000 operatives, and some authorities place at 300,000 the number of weavers thrown idle through the absence of yarn. The spinners refuse to submit their claim to arbitration, whilst the weavers would agree to arbitration on their own claim for an advance of 50 per cent.

The National Union of Railwaymen last week notified the Government and the Railway Executive of their intention to proceed with their national programme, which, among other matters, aimed at an eight-hour working day, and improved conditions. Various meetings dealing with the points at issue, were held, and on Thursday, the 5th inst., Mr. Thomas, the secretary of the Union, conferred on the matter with Sir Albert Stanley, the President of the Board of Trade. The subject also received the consideration of the Cabinet, and following this, the Government decided to concede the demands put forward by the railway operatives.

The unions concerned in the settlement are the National Union of Railwaymen and the Amalgamated Society of Locomotive Engineers and Firemen. Sir Albert Stanley first met the representative of the latter society ; he then had an interview with the Executive of the National Union of Railwaymen. The following is the text of the agreement arrived at with the Society of Locomotive Engineers and Firemen, which applies also to the drivers of electric trains and to cleaners :—

1. The principle of an eight-hour day for all members of the wages staff has been settled, and is to come into operation on February 1.

2. All existing conditions of service to remain unaltered pending the decision of a committee to be set up as soon as possible to review wages and other conditions of service of railwaymen in Great Britain.

Signed : Ernest J. Maggridge, on behalf of the Board of Trade ; and

W. W. Cooke, on behalf of the Associated Society of Locomotive Engineers and Firemen.

Speaking on the subject, Mr. Thomas said the settlement established that, as from February 1, 1919, the principle of the eight-hour day was to be instituted for all the wage staffs on the whole of the railways, including Ireland. Further, a committee was to be set up by both sides as soon as possible, to review wages and conditions of work. This committee will start operations immediately after the General Election.

We are informed that the clerical and supervisory staffs of the railways, who are practically unaffected by the settlement, intend to put before the Railway Executive Committee a list of demands for the improvement of their salaries and status.

Arrangements have been made for a conference between representatives of employers' organisations in England and Scotland, together with representatives of the Iron and Steel Trades Federation and the Amalgamated Steel Workers of Scotland for the purpose of considering the establishment of an eight-hour day throughout the steel trades.

It is reported that the National Transport Workers' Federation is making immediate application for an increase of 10*s.* per week in the war wage at present paid to carters, motormen, and kindred workers. Following the lead of the railwaymen, the Federation is also demanding an eight-hours' day and a five and a half days' week, time and a half for overtime, and double pay for Sundays.

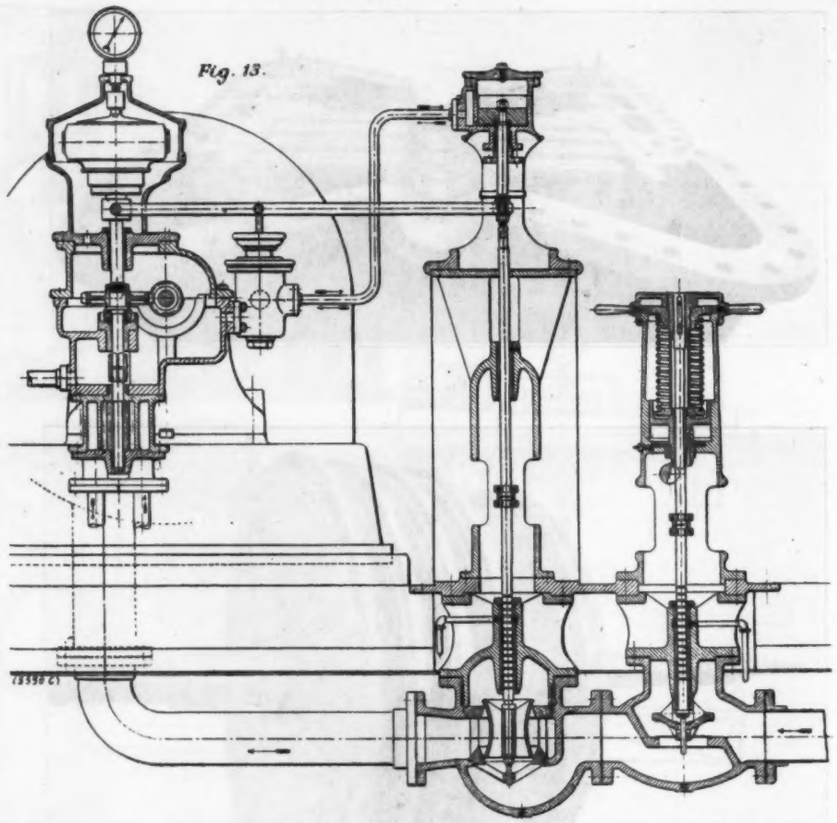
On the occasion of the last meeting of shareholders in the Barrow Hematite Steel Company, the chairman, Mr. Mure Ritchie, says the *Sheffield Daily Telegraph*, referred to the company's acquisition of further large iron-ore interests in Cumberland, spoke of the new furnace then almost completed, and foreshadowed economies which would save the company many thousands of pounds a year. Replying to a question, he said there was no prospect of amalgamation with the Millom and Askam Hematite Iron Company, but in the report for 1917, just issued with that for the previous year, it is stated that the Millom concern and the North Lonsdale Iron and Steel Company have joined with the Barrow Hematite Steel Company in acquiring an interest in the Ullcoats Mining Company, Cumberland, thus further assuring themselves of a supply of high-class ore. The report refers also to the 5 per cent. dividend to be paid on December 31 on the ordinary shares, the first for ten years, and shows that the sum carried forward to the current year is 221,336*l.*, against

LAND AND MARINE STEAM TURBINES.

CONSTRUCTED BY THE ATLAS ENGINEERING COMPANY, COPENHAGEN.

(*For Description, see Page* 675.)

Fig. 13.



125,320*l.* brought in. For the two years reviewed nothing is written off for depreciation, but large appropriations are made to a special reserve fund which now amounts to 200,000*l.* The reports reveal a strong position and good prospects.

A Local Government Board inquiry was held at Lincoln last Tuesday, with reference to an application by the Corporation to borrow 250,000*l.* for electricity purposes. The Town Clerk, Mr. W. Bagshaw, stated that the application was to enable the Corporation to acquire Messrs. Clayton and Shuttleworth's electric-power station, and to extend and adapt it as a generating station for supplying power to the large engineering works in the City and to the public. The scheme was the outcome of advice given by Sir John Snell. The pre-war industries of Lincoln were mainly the manufacture of agricultural machinery, traction engines, &c., and it was anticipated that they would now be reverted to with increased activity. The engineering firms were contemplating very considerable extensions, and there would be a great increase in the demand for electric power.

Sir John Snell added that Lincoln being 30 miles from any likely source of supply, the only alternative open to the City was to develop its own power supply. The present station of the Corporation was inadequate, and he came to the conclusion that the proper course was for the Corporation to take the responsibility of putting down an adequate power station, which would not only supply the needs of the city in years to come, but would immediately meet the urgent demands of the great industries. Eventually, at the Corporation's request, he entered into negotiations with Messrs. Clayton and Shuttleworth for the acquiring of their electric-power station, and agreements had been entered into with that firm, and with Messrs. Ruston and Hornsby, for the supply of power for eleven years.

The State Mining Engineer's Report on the Queensland Mines for 1917 states that during the year the average number of men employed in metalliferous mines was 6,574, in coal mines 2,229, and in connection with the treatment of ores at mills, smelters and other works on surface the number was 2,354. The total number for all mines, mills and other works, for the period under consideration, was, therefore, 11,157 which, compared with the corresponding figure for the previous year, 11,767, shows a decrease of 610. The figures representing the quantity and value of minerals produced from the various mining districts, taken as an indication of the progress of mining operations during the year, disclose generally a less satisfactory result than that shown by a comparison of the records for the two previous years—inasmuch as, with the exception of the coal-mining districts and several of those responsible for the part of the production of copper, tin and rare metals, the production in most cases shows a falling off to some extent.

There was a substantial increase in the value of copper from the Cloncurry district and in tin, &c., from some of the far northern districts, in both cases due largely to mines previously in the developing stage having become productive during the year, but the largest increase in value, viz., that in the coal-mining districts, which has in a great measure balanced decreases shown elsewhere, is due more to the higher value of the coal than to any large increase in production, though certainly a better record is shown with regard to the quantity of coal produced for the year.

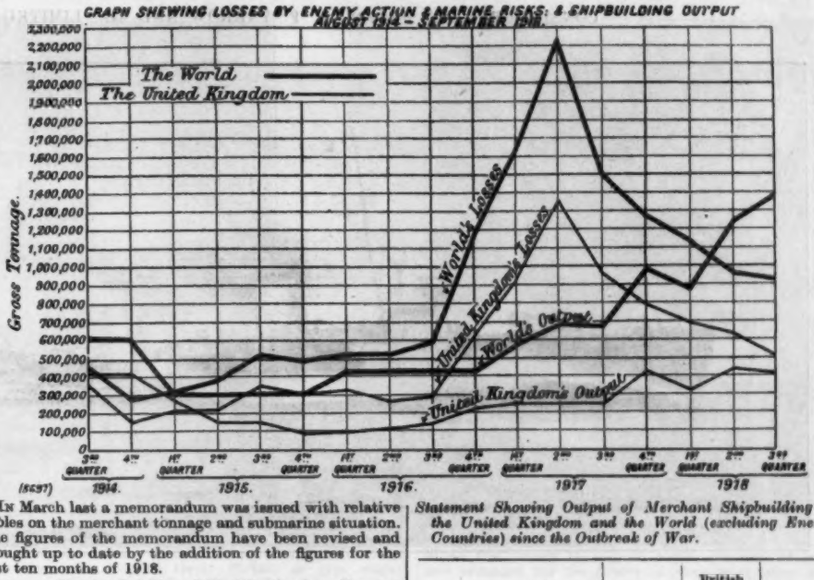
The report also states that efforts were made early in the year, in which the Department assisted in every way possible to encourage coke making and improve the prospects of that industry at North Ipswich, but very little result was achieved. A certain amount of development was done in the collieries in the Ipswich district, one or two new tunnels being started and ventilating shafts sunk, &c., but nothing in this connexion calls for special mention.

Two other seams, 4 ft. 6 in. and 4 ft. 2 in. respectively, were met with in the Newcastle shaft above and below the big seam, the lower one being inferior to the uppermost one. A quantity of graded coal from Blair Athol was shipped to a northern port during the year and may lead to augmenting the future production of the field. The old workings of the Co-operative Colliery at Blair Athol, which were flooded at the end of 1916, were not reopened, but a tunnel was started during the year to work the seam at another place, and it is expected that this colliery will be producing coal again shortly.

At the Bluff Colliery in the central district work was carried on continuously for an output of a little over 6,000 tons, and operations were confined to the various seams previously broken off from the main dip.

Considerable extensions were made at the Mount Mulligan Colliery in the No. 2 seam and work is being pushed forward in the No. 1 bottom seam, a portion of which, some 2 ft. in thickness, it appears from experiments, is equally suitable for coking as the coal in No. 2 seam.

BRITISH AND WORLD'S MERCHANT TONNAGE LOST THROUGH ENEMY ACTION AND MARINE RISKS.



IN March last a memorandum was issued with relative tables on the merchant tonnage and submarine situation. The figures of the memorandum have been revised and brought up to date by the addition of the figures for the first ten months of 1918.

Statement Showing British and World's Merchant Tonnage Lost through Enemy Action and Marine Risks since the Outbreak of War.

Period.	British.	Foreign.	Total for World.
1914.	gross tons.	gross tons.	gross tons.
August and September ..	341,824	85,947	427,771*
4th quarter	154,728	126,688	281,416
1915.			
1st quarter	215,905	104,542	320,447
2nd quarter	223,676	156,743	380,419
3rd quarter	356,659	172,822	529,481
4th quarter	307,139	187,234	494,373
1916.			
1st quarter	325,237	198,958	524,195
2nd quarter	270,690	251,599	522,289
3rd quarter	284,358	307,681	592,039
4th quarter	617,563	541,780	1,159,343
1917.			
1st quarter	911,840	707,533	1,619,373
2nd quarter	1,361,870	875,064	2,236,934
3rd quarter	952,938	541,535	1,494,473
4th quarter	782,889	489,954	1,272,843
1918.			
1st quarter	697,668	445,668	1,143,336
2nd quarter	630,862	331,145	962,007
3rd quarter	512,030	403,483	915,513
October	83,952	93,582	177,534
Totals	9,031,828	6,021,958	15,053,786

* This figure includes 210,653 gross tonnage interned in enemy ports.

NOTE.—Tonnage lost by enemy action since October 31 British, 11,916; foreign, 2,150.

Three statements are attached, showing for the United Kingdom and for the world, for the period August, 1914, to October, 1918:—

1. Losses by enemy action and marine risk.
2. Merchant shipbuilding output.
3. Enemy tonnage captured and brought into service.

Since the issue of the previous memorandum, the output of the merchant tonnage of the world has overtaken the losses, and during the seven months, April to October, new construction has exceeded losses by more than 1,000,000 tons.

The following table summarises the position of world tonnage on October 31:—

		Gross Tons.
Losses		15,053,786
Gains—		
New construction	10,849,527	
Enemy tonnage captured...	2,392,675	
		13,242,202
Net loss		1,811,584

The position as to British tonnage on October 31, exclusive of transfers to and from the British flag, was as under:—

		Gross Tons.
Losses		9,031,828
Gains—		
New construction, United Kingdom	4,342,396	
Purchases abroad	530,000	
Enemy tonnage captured...	716,520	
		5,588,916
Net loss		3,443,012

Statement Showing Output of Merchant Shipbuilding of the United Kingdom and the World (excluding Enemy Countries) since the Outbreak of War.

Period.	United Kingdom.	British Dominions, Allied and Neutral Countries.	Total for World.
1914.	gross tons.	gross tons.	gross tons.
August and September ..	253,290	337,310	1,012,920
4th quarter	422,320		
1915.			
1st quarter	266,267		
2nd quarter	146,870	551,081	1,302,000
3rd quarter	145,070		
4th quarter	92,712		
1916.			
1st quarter	95,566		
2nd quarter	107,603	1,146,448	1,688,000
3rd quarter	124,961		
4th quarter	218,332		
1917.			
1st quarter	246,239	340,807	587,046
2nd quarter	249,331	435,717	685,048
3rd quarter	248,283	426,778	675,061
4th quarter	419,621	571,010	990,631
1918.			
1st quarter	320,280	550,037	870,317
2nd quarter	442,966	800,308	1,243,274
3rd quarter	411,395	972,735*	1,384,130
October	156,100	375,000*	511,100
Totals	4,342,296	6,507,231	10,849,527

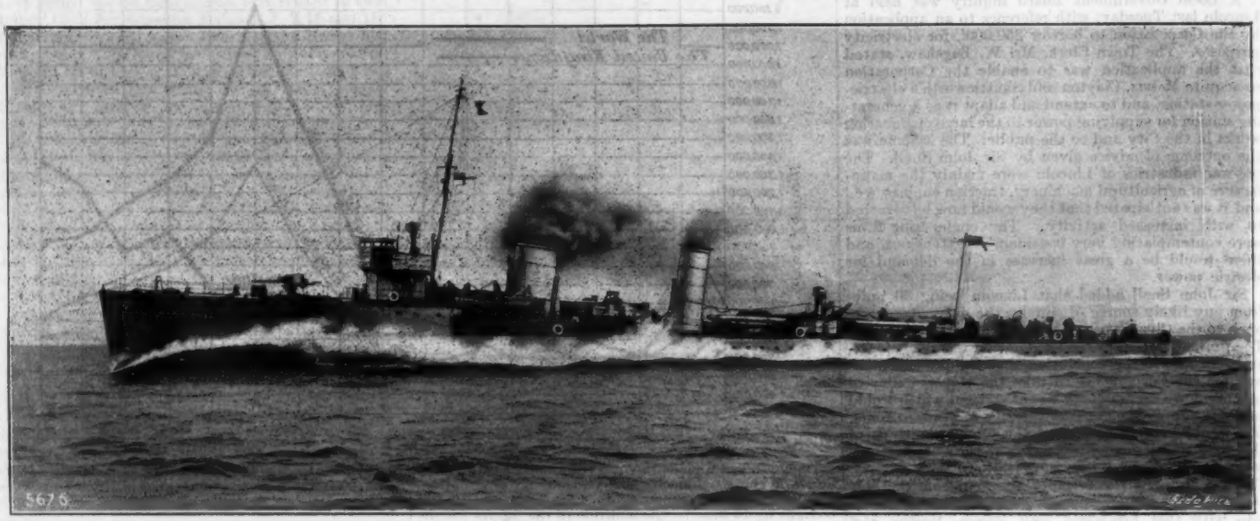
* Provisional figures.

Statement Showing Enemy Tonnage Captured and Brought into Service by United Kingdom and by Allies (excluding Russia) since the Outbreak of War.

Period.	United Kingdom.	Allies.	Total.
1914.	gross tons.	gross tons.	gross tons.
August and September ..	654,037	51,162	705,199
4th quarter	18,269	9,482	27,751
1915.			
1st quarter	5,153	3,545	8,698
2nd quarter	458	88,489	88,947
3rd quarter	5,322	—	5,322
4th quarter	2,204	—	2,204
1916.			
1st quarter	—	244,775	244,775
2nd quarter	2,073	976	3,049
3rd quarter	23,821	171,116	195,937
4th quarter	—	—	—
1917.			
1st quarter	—	—	—
2nd quarter	—	656,480	656,480
3rd quarter	5,186	333,731	338,917
4th quarter	—	116,399	116,399
1918.			
1st quarter	997	—	997
2nd quarter	—	—	—
3rd quarter	—	—	—
Totals	716,520	1,676,155	2,392,675

H.M.T.B. DESTROYER "MOUNSEY."

CONSTRUCTED BY MESSRS. A. F. YARROW AND CO., LIMITED, ENGINEERS, GLASGOW.



Destroyers, as is well known, have played a leading part in the defeat of Germany at sea. Not merely did they get home again and again on the German Fleet as it fled from the Jutland battle, but the destroyers have been the terror of the U boats. For obvious reasons it has not been possible to publish until now any details of the more recent of our additions to these craft, but the declaration of the Armistice has relaxed the restrictions in vogue, and we are thus enabled to give an illustration and some particulars of the destroyer Mounsey, the boat which, under the command of Lieutenant Craven, saved, under circumstances of very great difficulty, no less than 696 lives when the Otranto was torpedoed on October 6 last. The sea at the time was exceedingly rough, and it would have been fatal to have brought a lightly constructed vessel like the Mounsey alongside of the cruiser. The saving of life was therefore effected by maintaining the Mounsey under way, so that she passed the Otranto within a few feet, allowing the people to jump from one ship to the other. The manœuvre had to be repeated many times, and was, under the circumstances, a very original and successful method of rescuing those endangered without great risk to the destroyer herself.

The Mounsey was built by Messrs. A. F. Yarrow and Co., Ltd., at their Scotstoun works, and on her measured mile trials attained a speed of over 39 knots. This trial was run with the boat fully armed and equipped, and with sufficient fuel on board for a run of 1,000 miles at an economical speed. Further particulars are given below.

Length between perpendiculars	260 ft. 3 in.
Length overall	271 ft. 6 in.
Beam	25 ft. 7½ in.
Depth, midships	16 ft. 3 in.
Total heating surface	22,017 sq. ft.
Four hours' trial—	
Draught forward, 8 ft. 1½ in.; draught aft, 8 ft. 2½ in.	835·3 tons at yard.
Speed, 4 hours	38·605 knots.
Speed on measured mile	39·018 knots
Revolutions per min. 4 hour trial	685·6.
Revolutions per min. on measured mile trial	693·02.
Oil consumed in 4 hours	57·33 tons.
Load on trial	158 tons.
Oil fuel capacity	228 tons.
Radius of action at full speed	615 miles.
Armament—	
Three 4-in. quick firers; two 2-pounders; two twin 21-in. torpedo tubes.	
Complement—79.	

Particulars of Runs on Measured Mile.

No.	Hours p.m.	Boiler Steam.	Vacuum.	Air Pressure.	Revolutions.	Time on Miles.	Speed.
1	1·45	259	28	6·5	689·0	1–32·4	38·962
2	1·54	257	28	6·5	692·0	1–32·4	38·962
3	2·4	257	28	6·5	693·6	1–32·2	39·056
4	2·13	258	28	6·5	693·5	1–32·0	39·130
5	2·24	258	28	6·5	694·0	1–32·0	39·710
6	2·34	259	28	6·5	692·75	1 31·4	39·398
Mean on measured mile		258	28	6·5	693·023		39 018
Mean in 4 hours		258	28	6·4	685·6		38·605

It may be added the first Italian vessel to enter the port of Trieste was the Audacé, which was built by Messrs. Yarrow and Co. eighteen months ago.

THE PRESENT POSITION OF GERMAN ROLLING-STOCK.

In almost every direction Germany finds herself in a most serious plight, and the shortage and disrepair of rolling-stock is not the least important factor. Before the war Germany had about 700,000 goods wagons and 30,000 locomotives. The number of the latter, as of the former, has certainly been increased during the war, through seizures in Belgium and France, but on the other hand some 4,000 locomotives may be looked upon as at least temporarily unavailable, being at present stranded in often remote occupied territory. As far as a portion of these 4,000 engines is concerned, it is doubtful whether they will ever return. Some 8,000 locomotives are badly in need of repair. Thus the 5,000 locomotives which have to be handed over, according to the terms of the armistice, represent about one-fourth of those available, and efficient. Apart from this there is some doubt as to whether or not the locomotives of the Alsace-Lorraine State railways are included in the above 5,000 engines. The proportion of increase and decrease as regards wagons may be taken to be about the same as with the locomotives. The question then remains to what extent German works will be able to make good the compulsory surrender of these 5,000 engines, for of the purchase of locomotives from abroad there can be no question at present. The capacity of the German locomotive factories is at the present moment, with some reserve, put at 2,500 large locomotives per annum. This estimate, of course, is subject to sufficient raw materials and other necessities being available as well as a sufficiency of skilled and trained and willing labour. If it really were possible satisfactorily to overcome these and other difficulties, and also in other ways to return to an ordered state of affairs, and entirely to ensure and rely upon the large left-Rhine production of raw materials for the whole reconstruction period, it would take the German railways two or three years to recover from the blow which their defeat has entailed. During this considerable period German industry would be entirely debarred from export of full-size locomotives and confined to narrow-gauge engines, of which it can supply some 1,500 in the year. The position is made additionally difficult, because Germany has to deliver up efficient locomotives, so that those which remain include all those more or less unfit for use. The repair of these, in addition to that of the 8,000 locomotives referred to above, will be very difficult to effect, but as the State railways are compelled to exercise the greatest economy these repairs will probably first be proceeded with.

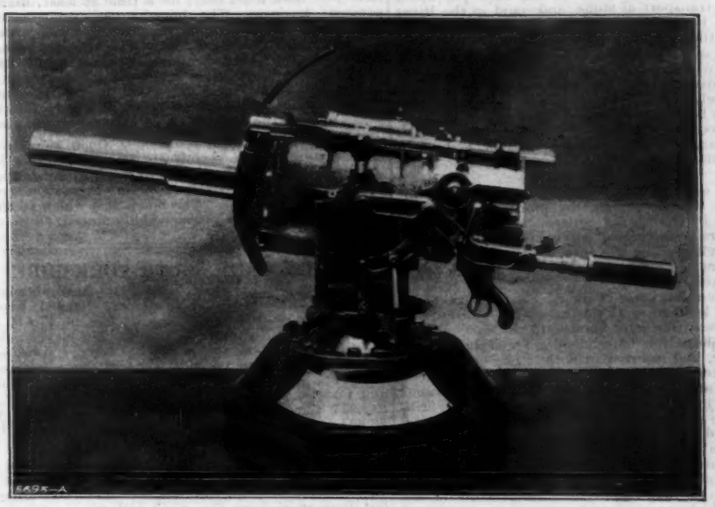
It is being suggested in Germany that firms which have not formerly gone in for the building of locomotives, of which the majority have been engaged in war work, might with advantage take up the manufacture of locomotives, as the Allgemeine Elektricitäts Gesellschaft already has done.

As regards the building of goods wagons the capacity of the German works during the last few months of the war has been put at 50,000 per annum. In case all necessary raw materials which are nearly all produced within the country, be made available and the industry not be handicapped by other adverse circumstances, the above-mentioned capacity might perhaps be increased by 50 per cent. Even then it will take Germany three years to replenish her stock of goods wagons. In view of the eight hours movement it is deemed likely that the cost per ton of locomotive and wagon weight for some considerable time to come will remain at something like the present high figures.

Purification of Ferruginous Kaolin.—Many of the kaolin deposits in Bohemia and Moravia are too rich in iron to be of any value, and the purification of such minerals is a difficult matter. Doctors Jaroslan Milbauer and F. Skutil hence investigated the working-up of kaolin refuse from various sources, trying a large number of processes (*Chemiker Zeitung*, October 30, 1918). The material contained quartz and feldspar and was received calcined or uncalcined. They found that calcination was necessary to get rid of the iron, and that it was best effected at 700 deg. C., the material being mixed with sawdust (as reducing agent) and the air excluded. The calcined kaolin is then dissolved in sulphuric acid of 50 deg. Baumé; the iron passes into solution as ferrous sulphate and remains in the mother liquor, whilst crystals of alum or aluminium sulphate are deposited. These are not free from iron, however, and have further to be purified. The Griesheim-Elektron Company redissolves the alum or aluminium sulphate in hot sulphuric acid; this process is difficult, however, and to be recommended only for working on a large scale. The simplest way is to precipitate the iron in the ferric condition by yellow prussiate of potash after having added infusorial earth to the solution in order to facilitate the filtration: 99 per cent. of the iron can thus be removed. Reduction of the ferric to ferrous iron and crystallisation in an indifferent atmosphere also gave good results. Treatment of the raw material with SO_2 or gases from roasting furnaces or with producer gas, extraction with hydrochloric acid, and further treatment of the alum with various chemicals did not answer so well.

Determining the Rate of Gas Flow.—The ordinary gas meters with revolving drums are not very reliable for gas current of small speeds, and in laboratories, where slow rates of feed are frequently required use is generally made of meters depending upon determinations of pressure differences. Of this class again instruments for relatively high pressures (rota meters, *e.g.*) are more reliable than instruments suitable for gas flow under a head of a few inches of water. Professor E. H. Riesenfeld, of Freiburg in Baden (*Chemiker Zeitung*, October 19, 1918) recommends a modification of the differential-pressure gauge of Normann, known as capometers. His gauge consists of a vertical U-tube, the limbs of which are so bent that they form a T; the vertical portion consists of the two limbs in close juxtaposition, and these limbs are then bent off at right angles to be horizontally in alignment. The junction of the limbs is bridged over by a shunt tube containing a capillary portion; the gas flows partly through the U-tube, therefore, and partly through the capillary, the two circuits being in parallel. The capillary has an internal diameter either of 0·2 mm. (for heads of about 15 cm. of water) or of 0·4 mm. (for heads of 30 cm.); Riesenfeld prefers the narrower capillary. The U-tube which is calibrated may be up to 1 m. in length; the tube is filled with paraffin oil, petrol ether, water, mercury, solution of zinc iodide, &c., according to the nature of the gas. Readings are obtained correct within 0·1 per cent., and even of higher accuracy. The chief point in which Riesenfeld's instrument differs from those of Normann and Ubbelohde is that the latter made use of a detachable capillary which is joined up with the aid of rubber tubing; with that arrangement the gas flow is apt to become turbulent.

MODEL NEW TYPE 6-POUNDER TANK GUN.



THE illustrations on this page are reproductions of photographs of a model of a new type 6-pounder tank gun. An idea of the dimensions may be gathered when it is explained that the diameter of the base is about 8 in. The model is exact to scale in every detail, and goes through all its operations as completely as does its original. It has been constructed by the workmen at Ponders End Shell Works, at their own expense, since Armistice Day, and has been presented by the employees, at the termination of the great war, to Mr. H. S. B. Brindley, the general manager, as a sincere tribute to his leadership, and to his devotion to the great cause.

PIVOTAL MEN.

TO THE EDITOR OF ENGINEERING.

SIR,—In a leading article in to-day's *Times* occurs the following sentence: "These men have been labelled 'pivotal,' which means that their work is a necessary preliminary to the employment of others." The fact that the word pivotal is marked by inverted commas shows that it is being used in a new sense, and that *The Times*, which prides itself on the correctness of its English, rather shies at this addition to our vocabulary. The word itself is, of course, quite old in a mechanical sense, and in the new sense it has, during the past few weeks, appeared hundreds of times in the daily press, often being prominent in head lines.

The war has been responsible for the introduction of many new words and for the assignment of new meanings to old words, and it would be an interesting task to make a list of them and to trace their origins and the connection of ideas which gave rise to them. In many cases, I fear, it will be difficult to name the author of new expressions, or even to suggest what train of reasoning or analogy gave rise to them. If this is to be done someone must set about it at once before those who were present at the birth of a new word have forgotten all about it. As a contribution to this inquiry may I point out that the word pivotal appeared in a leading article in your Journal on April 18, 1917, and that it struck me at the time as having a new and specific meaning which made it an efficient and desirable substitute for a complex phrase. The article in question analysed the matter of indispensability in men and adopted the word pivotal as a more exact and specific description than indispensable.

Evidently the writer of the article found the word pivotal very apt to express his meaning, for he used it 11 times, and since then it has been adopted as a Government classification. If would be very interesting to know if any prior use of the word pivotal in the new sense can be found, for if not, it would appear that ENGINEERING has passed into general currency a significant term which meets the eye at every turn.

Yours truly,

"ETYMOLOGIST."

December 10, 1918.

"STUDENTS FOR DEGREE COURSES."

TO THE EDITOR OF ENGINEERING.

SIR,—In reference to Mr. T. Roland Wollaston's letter in your issue of the 29th ult., on the above subject, may I remind him and the soldiers to whom he so naturally gratefully refers that the University of London has, from the institution of its degree of B.Sc. in the Faculty of Engineering, always allowed candidates to prepare for it by attending evening classes or by any other method that they care to adopt. This applies to all its degrees except the medical ones, and has proved the making of many a man and woman, London being the first university in Great Britain to give women degrees. (Oxford and Cambridge allow them to sit for the examinations, but do not yet grant them the degrees when they pass!)

The facilities thus afforded by the University of London should be carefully guarded and be more widely known. One further fact must, however, be added, namely, that for some exceedingly shortsighted reason the Institution of Civil Engineers has recently refused to accept such an "external" degree, as it is called, in lieu of their own entrance examination for membership. This, however, will probably be a greater disadvantage to that Institution than to the graduates.

Yours very truly,

ALFRED S. E. ACKERMANN.

25, Victoria-street, Westminster, London, S.W. 1.
December 6, 1918.

TO THE EDITOR OF ENGINEERING.

SIR,—While there is general sympathy with students whose courses have been interrupted by military service, it is doubtful whether many of them have been able—as your correspondents imply—to continue their professional studies. It is clear that a degree cannot be granted to any candidate, whatever his war service, who does not satisfy the examiner that he has attained the pre-war standard, without thereby doing an injustice to those who have already obtained the degree.

To meet the present difficulties this college is making arrangements to give a full year's course to engineering students who are able to enter in January next. It will necessitate such student working through part of the Easter and summer vacations, but the whole work of the session will thus be covered.

It is desirable that those wishing to take advantage of these arrangements should take immediate steps in the matter.

I am, yours faithfully,

JAMES J. GUEST.

University College, London, N.W. 1.

SANDWICH HAVEN.

TO THE EDITOR OF ENGINEERING.

SIR,—The recently published accounts of Sandwich Haven (described as "the Mystery Port) and the record of the extensive works carried out there for war purposes, have naturally excited much popular interest, and have led to just praise of the War Office engineers who achieved such immense results in so short a time. Speed is naturally the test of success in such a case, outweighing both economy and permanent utility, and the Royal Engineers deserve the praise given to them, but it ought to be known to the public as well as to engineers, that plans were prepared long before the war to carry out similar but of course less extensive works at Sandwich Haven for commercial uses, but especially in preparation for the coming export trade in Kent coal. Under the exigencies of the war and the pressure of D.O.R.A.—under whose auspices the War Office took possession of the site—the plans were necessarily laid aside. Perhaps you will allow the history of the suspended scheme to be stated.

The suitableness of Sandwich Haven to become a great commercial harbour, given the local trade to maintain one, has been manifest to engineers for generations, and many schemes are recorded, though they have always fallen through for want of assurance that such local trade would arise. This assurance was at length given by the discovery of coal in Kent and the consequent prospect of the rise of a great industrial district around Sandwich. As early as 1907 some local residents, disregarding the then general unbelief in the coalfield, found the money to acquire some hundreds of acres, and arranged for the future acquisition of other large areas of the land and foreshore required for the development of an important commercial harbour.

Recognising that an export trade in coal could not arise for a few years, they utilised the land (good grazing land since it was embanked and drained in very early times, and by no means "marsh land," as has been suggested) for agricultural purposes, and for the use of a local golf club.

In 1911 matters had so far progressed that the owners formed amongst themselves a small pioneer syndicate, the Sandwich Haven Wharves Syndicate, Limited, and appointed me as their engineer (also as chairman of the syndicate). A provisional understanding was come to with the Corporation of Sandwich with reference to their extensive and very ancient rights over the Haven, and in 1913 plans for the harbour work, with detailed estimates, were prepared by me, in conjunction with my friend Mr. A. E. Carey, M.Inst.C.E. Preparations were also made for applying to Parliament in 1914 for an Act under which a public Harbour Board was to be constituted for the control of the harbour, as distinct from the wharves upon it. The war, as already said, suspended everything, and the War Office has since been in occupation of nearly the whole property and of other adjoining land as well. It has carried out plans which, in view of their urgency and great national importance, as well as of the special nature of the work, are exempt from criticism by ordinary standards, while their value for national purposes, if developed after the war, is undoubted. In adapting them for peace uses the principal features of the original plans will probably need to be incorporated with what has been done.

One of the earliest promoters of the scheme upon its commercial side was the late Mr. W. A. Hubbard, for many years Town Clerk of Ramsgate. The advantage of Sandwich Haven as a cross-Channel port (I am inclined to say as *the* cross-Channel port) was well understood by him, and even the train ferry as now carried out, and starting from exactly the same point, was included in his proposals. The physical advantages of the site for harbour purposes are extraordinarily great, and are probably unequalled at any point save Southampton (and possibly Falmouth) between the Land's End and the Thames. The mud-flats of Pegwell Bay, ignorantly supposed to ensure failure, are in reality a helpful feature, and it may be added that the idea that Sandwich Haven can be adapted only to small or light-draught vessels is entirely mistaken; vessels drawing considerably over 20 ft. can readily be provided for.

With the return of peace, it is to be hoped that those who long since foresaw and planned a work of such importance to the country, and spent their money in preparing for it, may be permitted to carry out and reap the reward of their labour and their expenditure, either independently or in association with the military authorities. The River Stour gives facilities not only for a great commercial harbour at its mouth, but for important military works higher up, which indeed exist already, and there is no reason the two should not mutually assist each other.

Your obedient servant,

MARK ROBINSON, M.Inst.C.E.

Sandwich Haven Wharves Syndicate, Limited, Gwydir Chambers, High Holborn, December 11, 1918.

"TONNAGE IS PROSPERITY."

TO THE EDITOR OF ENGINEERING.

SIR,—In your article "Tonnage is Prosperity" in this week's issue you emphasise the oft-repeated call for efficiency in industry, and effort on the part of the

workers. How is this efficiency and effort to be obtained? It has been proved beyond question that as an efficient organisation, capable of unheard-of efforts, the British Army is supreme.

Now the material of which the British Army is composed is exactly the same material as that which constitutes the industrial army, but we read that in the fighting army the spirit that exists between officers and men is the secret of its success. Is it not possible to infuse this spirit into the industrial army? I think it is, for the spirit is born of confidence in and sympathy with one another, as between officers and men.

I venture to suggest that in the proper selection of the officers in our great industrial works lies the real cure for unrest and dissatisfaction and restricted output.

I wonder how many of our industrial officers realise how minutely their actions are studied and their personalities and characters are analysed by the humble but, in the majority of cases, shrewd and thoughtful workmen. The personality of the manager and that of his assistants is reflected in the general attitude of the men

To gain the confidence of the men a manager or assistant must, above all, be thoroughly versed in his profession, and able to demonstrate his superior knowledge and experience when occasion arises; and in all respects he must conduct himself as a man and a gentleman. Given confidence in their officers, the response of the men will follow; and from long and intimate association with all classes of workmen, shop stewards and others, I am convinced the British industrial army is, like its prototype, ready to face any odds and win, under proper leadership.

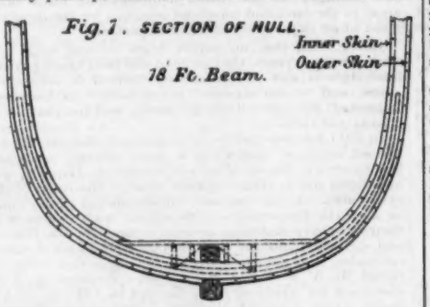
Yours truly,

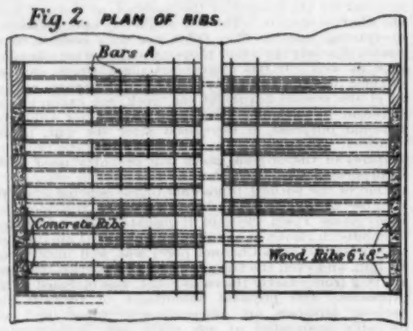
Glasgow, Dec. 10, 1918. "Shop Manager."

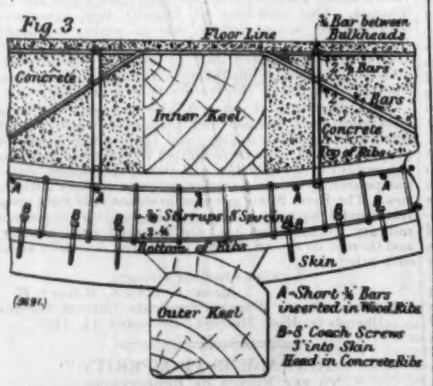
FERRO-CONCRETE REPAIRS TO WOODEN SHIPS.

To the Editor of Engineering.

Sir,—A good deal has been heard of late, and a good many plans published, of ferro-concrete construction as







applied to ships and steamers, and it is becoming increasingly evident that this type of craft has come to stay. We think, however, that we have broken new ground in some work which we have just completed, and which consists of repairs to a wooden ship, effected by means of ferro-concrete.

The circumstances are briefly these: A wooden ship of some 200 tons displacement having been purchased by us for the transport of stone and sand in the River Plate estuary, it was found on placing her under the tip wagons, that the impact of some 5 tons of stone falling from a height of 15 ft. caused her to leak badly, and on investigation it was found that the wooden ribs of the vessel were entirely rotted away for some 3 ft. on either side of the keel, and the good state of the wooden skin alone kept the bottom from collapsing.

It was judged that the boat in this state could not be docked by means of a slipway, the only means of docking available at the time, as the ribs were not fit to stand the weight.

As the boat was urgently required, it was decided that a good repair might be made by placing new ribs of ferro-concrete in the spaces between the wooden ribs, and the repairs were carried out on these lines, at the same time strengthening the false keel by running two continuous concrete girders parallel to it on either side, and tied into the ribs.

It will be seen that some of the rib bars were taken up over the false keel, so as to tie this to the bottom, and the new concrete ribs were bonded to the wooden ribs, by means of short iron bars reaching from one wooden rib to another, and inserted in both. The bond to the skin was effected by means of heavy coach screws which were screwed into the skin planks, the heads and washers being buried in the concrete ribs. The concrete ribs were taken up sufficiently far to be sure of a good bond with the sound part of the wooden ribs, which were in good condition away from the keel.

The whole of the work was done in a few days while the ship was afloat in a light condition, and the added weight was very little more than the ballast of old chains, &c., which it was customary to use in this vessel, and which was, of course, dispensed with.

We should be very glad to know if this method of repairs has been used by any of your readers, and may say that the ship thus repaired stands successfully the rough treatment referred to above, and we have no reason to doubt that she is now as strong as when built. The concrete used was a mix of agate gravel and sand, in the proportion of 1 : 2 : 3, with Saylor cement.

We may say that the naval experts are rather puzzled to give an opinion on the repair, but we have not heard any sound reasons advanced by them for not approving the job.

It is evident that the repair was considerably facilitated by the intervals between the ribs being of dimensions suitable to allow of a good substantial rib of concrete being moulded in its place between the wood ribs, with four or six bars and the corresponding stirrups as shown by the sketches.

Yours faithfully,

Hume Brothers.

201 San Martin, Buenos Aires, October 2, 1918.

NOTES FROM THE NORTH.

Glasgow, Wednesday.

Scotch Steel Trade.—Notwithstanding the fact that many Government orders have already been cancelled great activity prevails at the local steel works, where there is much pressure by consumers for delivery of steel of all descriptions. All over the conditions are highly satisfactory and it is expected that there will be a constantly increasing demand for machinery and constructional material for France and Belgium, especially now that the refugees are being repatriated. The war work which our own Government has still to put through will call for large quantities both of finished and semi-finished steel to be produced with the utmost despatch, besides which the claims of the ordinary mercantile consumer—so long set aside—must now receive every consideration, and makers are certainly giving preference in the meantime to the home requirements. Naturally, some little time must elapse before working conditions and markets return to their former levels, but with a plentiful supply of good orders on hand, and daily inquiries from all quarters, steel-makers are assured of a sufficiency of work to keep every rolling mill in the West of Scotland fully employed for a lengthened period, even although there be some uncertainty as to what will follow later on. Steelmakers and Government officials in consultation have now fixed the new rates which will ensure to buyers, both at home and abroad, a certain guarantee of protection for some time at least. So far as finished material is concerned it is expected that the export price will come out about 5*l.* per ton over the home rate.

Malleable Iron Trade.—Work in the malleable iron trade still runs on a very satisfactory basis, order books being well filled and inquiries numerous, the new and record rates notwithstanding. The fixing of bar iron at 30*l.* per ton has been arrived at with a definite point in view, but fears are expressed that once the more urgent and necessary orders are fulfilled makers may find things at a stagnation level. Meantime consumers seem to desire some sort of guarantee that prices will not be broken for a given period—a few months at least. What effect these fixed prices may ultimately have upon trade, and especially the export trade, it is as yet difficult to compute. Business at the moment, however, is excellent with every mill running to its fullest capacity.

Pig-Iron Trade.—Pig-iron continues in steady demand, everything produced going speedily into use, while inquiries are pouring in from every quarter of the globe as to quantities available and shipping prospects. Despite this activity, however, conditions are rather unsettled and some makers are simply turning out the material for which priority claims have been established. While the home demand is heavy the export prices which have just been fixed may, for a time at least, limit the overseas business. The home rates, too, remain as they were, and the export price has been advanced to a fixed maximum amount, in most cases to the extent of 2*l.* 10*s.* per ton over the home level, finished material being about 5*l.* per ton in excess. The sooner that makers are in a position to meet the requirements of their overseas customers the better it will be for themselves and for the country under existing circumstances.

Removal of the Clyde "Boom."—Once more inward and outward bound vessels are free to enter or leave the Clyde without examination by the Government patrol boats, a proceeding which has been in force since the early days of the war. The boom also which stretched right across the Firth is now being removed.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Hull Coal Trade.—In November, 190,434 tons of coal were imported to Hull, a decline of 17,472 tons compared with November last year. The eleven months of 1918 have aggregated 2,428,200 tons, a decrease of 211,802 tons compared with the corresponding period last year. The district collieries were headed by Denaby and Cadeby Main with 19,475 tons for November and 212,717 tons for the eleven months, compared with 23,655 tons and 276,986 tons respectively during 1917. All collieries show a marked reduction.

South American Trade.—Sheffield manufacturers who are looking for means whereby they may utilise the vastly increased plant that has been installed during the last four years have this week had an opportunity of inspecting some 3,000 samples, part of a collection of 30,000 that have been obtained by the Department of Overseas Trade from all parts of the world, and representing articles that are in general demand in the South American countries. The exhibition has been arranged by the Department of Overseas Trade in conjunction with the Sheffield Chamber of Commerce with the object of giving the manufacturers of Sheffield and Yorkshire an opportunity of inspecting the class of goods that are in demand in Latin America countries.

Germany Must Pay.—The Sheffield Chamber of Commerce have passed the following resolution in regard to the terms of peace settlement. "That in the opinion of the Council of the Sheffield Chamber of Commerce no peace terms will be acceptable which do not include the utmost possible repayment by the enemy countries to Great Britain, the Dominions, and her Allies, of their cost of the war; failure to enforce this repayment would involve Great Britain, the Dominions, and the Allies in years of excessive taxation, which would cause discontent and poverty among the whole population; would cripple industry and commerce, and would indefinitely postpone the requisite public expenditure on necessary social reform and improvement."

Iron and Steel.—The outlook in the iron and steel trades of the district continues to improve from day to day. Among the most hopeful signs is the general cry for more labour. Those firms who have been specialising in munitions and armament work have naturally been seriously affected by the cessation of hostilities and some time must elapse ere they can get into full swing on new work. The greater part of Sheffield's productions, however, are equally available for war and peace, and many firms have been able to change over almost immediately on to arrears of orders for commercial work. A certain amount of difficulty has arisen in the fear that prices might suddenly drop, but this has to a great extent been overcome. New orders are coming to hand very freely, and there is abundance of work in sight. Skilled men and able-bodied labourers are badly needed, and all depends on the promptitude with which the demobilisation of this class of labour is carried out. Prices of iron and steel are to a great extent in the melting-pot, and it is understood will not become settled until the end of January, when we are promised from the Ministry of Munitions a new list of maximum prices of all classes of steel, for both home and export sale. This confusion, of course, is not conducive to business, and buying is at present largely from hand to mouth. A sign of the times is the forward movement developing in the cutlery trade, with the object of placing it upon a sound foundation of modern engineering practice. A series of lectures, which are largely attended, are being given at the university on the application of engineering methods to the industries concerned, and a Sheffield Cutlery Trade's Technical Society is in process of formation.

South Yorkshire Coal Trade.—The conditions in the South Yorkshire coal trade show but slight change. Some little improvement is noticeable in certain grades, but on the whole there is no material increase in the output, and supplies are still very short. For house sorts there is a pressing demand, and generally speaking merchants have a large number of orders on their books which they are unable to satisfy with the tonnage they are receiving at the depots. Prices continue at a maximum, but, with the small tonnage available for open market, sales are largely nominal. In manufacturing material there is little evidence of any marked improvement, notwithstanding the reduced demand for munition purposes. Stocks are almost non-existent, and requirements are consequently of a pressing character. The demand for large steams, on the part of the Admiralty, is maintained, and the steady expansion of the export trade makes a further heavy call on output. Slacks

are keenly inquired after for general industrial purposes. Blast-furnace coke is less active owing to the number of furnaces set down for repairs. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Demand for all qualities of Cleveland pig-iron is heavy. Output of foundry kind is still considerably below the normal, and as this description is in larger request than other kinds, the needs of customers are very difficult to meet. The truck supply shows little or no improvement, and the shortage greatly hampers distribution. Hope is expressed that trucks will be returned from France before very long. The very pressing demand for iron for neutrals does not meet with success, there being practically none available for such trade after the needs of home customers and the Allies have been met, and in addition it is still practically impossible to obtain licences for shipment to neutrals. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; and for export, No. 3 and the lower qualities are 145*s.* and No. 1 is 150*s.*

Hematite Iron.—Supply of East Coast hematite iron is no more than meets essential requirements, and distribution continues under official supervision, and is likely so to do until production increases. Home needs being so urgent less hematite is being shipped to the Allies for the time being, but the situation is by no means unsatisfactory. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use and 172*s.* 6*d.* for export.

Manufactured Iron and Steel.—Great activity characterises the finished iron and steel industries. Pressure for delivery of shipbuilding equipment, constructional steel and railway material is as pronounced as ever. Producers, however, are much hampered by the coal shortage. Some firms, in fact, find it impossible to keep going, and unless there is immediate unexpected increase in coal supply Christmas holidays promise to be of longer duration than usual. The following are among the principal market quotations for home consumption:—Common iron bars, 14*l.* 10*s.*; steel ship, bridge and boat plates, 11*l.* 10*s.*; steel angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; chequer plates, 13*l.*; steel joists, 11*l.* 2*s.* 6*d.*; heavy steel rails, 10*l.* 17*s.* 6*d.*; and steel billets, 10*l.* 7*s.* 6*d.* to 11*l.*; and quotations for export include the following: Common iron bars, 20*l.*; steel ship, bridge and tank plates, 16*l.* 10*s.*; steel angles, 16*l.* 2*s.* 6*d.*; steel boiler plates, 17*l.* 10*s.*; chequer plates, 18*l.*; steel joists, 16*l.* 2*s.* 6*d.*; heavy steel rails, 15*l.* 10*s.*; and steel billets, 13*l.* 10*s.* to 15*l.*

Ironworkers' Wages.—The average net selling price of iron plates, bars and angles for the past two months has been certified by the accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England at 15*l.* 6*s.* 3·69*d.*, as compared with 14*l.* 11*s.* 9·96*d.* for the previous two months; and the secretaries to the Board report that there will be an advance of 9*d.* per ton on puddling and 7½ per cent. on all other forge and mill wages, but intimate that in accordance with the Ministry of Munitions lines of settlement of January 3, 1918, and February 20, 1918, these advances will merge into the 12½ per cent. bonus and the 7½ per cent. bonus granted under those settlements.

Seaton Carew Works and the Furness Group.—Another combination of interest in the iron and steel trade has been effected on Teesside, the announcement being made that Seaton Carew Iron and Steel Company, Limited, has effected an alliance of interest with the Furness group. The new arrangement comes into force on January 1. This is the second big step taken this year by Lord Furness in the direction of extending his control of the iron trade, the works of Messrs. Cochrane and Co., of Middlesbrough, having previously been acquired.

Foreign Ore.—Demand for foreign ore is good, and business is expanding notwithstanding continued large imports on running contracts and the fact that makers have very considerable stocks.

Coke.—Coke keeps stiff. Supply, generally is very scarce, but needs of blast furnaces continue to be adequately met. Average furnace kind is 33*s.* at the ovens, and low phosphorus quality 35*s.* 6*d.* at the ovens.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—The position of the market generally is now extremely difficult. The shortage in the supplies of coal approaches something very much like a famine, and it seems almost futile to attempt to meet the demand. It is difficult to explain the stationary character of the outputs. At many collieries production is now lower than it was weeks ago. In certain districts this is attributable to disputes which are only too prevalent here and there throughout the coalfield. But apart from this factor complaints are reaching the market of what looks like a general slackening off in the production, and there is an impression created that, for some reason or other, an appreciable section of the miners are pursuing a policy of ca' cannyism. It is deplorable that such a situation should exist at a time when there is so much need for coal, and when there is almost a glut of tonnage available for shipment. It is suggested that the high wages which are being earned accounts, partly at least, for this regrettable state of affairs, as the workmen have not the inducement to put their best into their work. On the other hand there is no relaxation in the pressure of the demand for cargo and bunkers. In addition to the increasing requirements of France and Italy there is an expansion in the demand of American ships, and in the aggregate the commitments of the Government to allied consumers leave practically no coal at all free for shipment to neutral destinations. As a matter of fact even our commitments to the allied markets are in arrear, and during the coming weeks outputs will almost certainly be still further reduced. In the first place there will be a stoppage of work on the polling day at all those collieries situated in areas where there is a contested election, and very likely in other districts as well. It is true that the Coal Controller has banned the idea of a stoppage, but no heed will be taken to Sir Guy Calthrop's protestations. Then it is certain that there will be two or three days' holidays at Christmas, so that no hope of immediate improvement can be entertained.

Newport.—There are complaints of the short outputs of collieries in the Monmouthshire coalfield. The Newport docks are plentifully supplied with tonnage, but the ships cannot get the coal they want, and in spite of the pressure of colliery managers and of the promises of the men to the Government, production is declining instead of increasing. Shipments are almost exclusively on official account, and fears of a diminished production has led to the curtailment of supplies for export.

Miners' Strike Threat.—The decision of the delegates at the South Wales Miners' Conference last Saturday that seven days' notice be given on Monday to terminate contracts caused consternation in South Wales. This decision was arrived at in support of the workmen at the Bedwas Colliery who demanded the dismissal of the whole of the lower grade officials at that colliery. The men's leaders, however, have fortunately taken a definite stand against the attitude of the miners' delegates, and at a meeting of the Executive Council of the South Wales Miners' Federation held at Cardiff, it was decided to decline to act on the instructions of the conference. The Council issued a statement in which they pointed out the impossibility of the situation created, and that to act on the instructions would mean the demand for the dismissal of a large number of officials against whom no charge whatever had been made by the men. The matter, however, is not yet disposed of altogether, and another conference is convened for the 19th inst., to enable the conference to rescind the previous resolution, and there is just a possibility of a rather sharp contest between the leaders and the miners' delegates.

Resignation of Coal Board Chairman.—Mr. F. L. Davis, the chairman of the coalowners' side on the Conciliation Board for the Coal Trade of South Wales, has sent in his resignation. Mr. Davis has been the chairman of the Board since its establishment in 1903, and is one of the most prominent personalities in the Welsh coal trade. Mr. Davis gives as his reason for his offering to resign the fact of the altered circumstances in the industry brought about by State control which deprives the Conciliation Board of one of its most important functions—the regulation of miners' wages. Since November, 1916, this has been entirely in the hands of the Board of Trade and the Coal Controller. The coalowners have had Mr. Davis' resignation under consideration, but have not so far come to any decision on the matter.

UNIVERSITY OF LONDON, UNIVERSITY COLLEGE.—Arrangements have now been completed:—(1) To enable students, whose courses have been interrupted by war service, to resume them as nearly as possible at the point at which they left off; by rejoining at the beginning of the second term, January 13, 1919. (2) To enable students, who were unable to begin their engineering studies last October owing to war conditions, to begin them by entering next term, January 13, 1919. For both classes of students additional work will be provided during parts of the Easter and long vacations, so as to enable them to get in a full session's work between January and August, 1919. Arrangements of a like kind are in contemplation in the other faculties, and will be made if a sufficient number of entries are received on or before January 6, 1919.

ELECTRIC POTENTIAL GRADIENT AND ATMOSPHERIC OPACITY.—At the meeting of the Royal Society held on the 5th inst., C. Chree, Sc.D., F.R.S., submitted a paper on "Electric Potential Gradient and Atmospheric Opacity," at Kew Observatory. The author stated that it had been the practice for many years at Kew Observatory at the ordinary hours of meteorological observation to record the most distant of a selected series of objects which is visible at the time. Separate notes are also made of the presence of mist or fog. Thus a large amount of information has accumulated as to the greater or less opacity of the atmosphere. The present paper utilises the data for a comparison of atmospheric opacity and the potential gradient of atmospheric electricity. It is found that even for the smallest amount of opacity which the observation scheme is able to disclose, the value of the potential gradient increases with the opacity. The effect of mist or fog on the potential gradients recorded in winter is large, and there being a large diurnal variation in the incidence of mist or fog, there is consequently a noteworthy influence on the character of the diurnal variation of potential gradient.

NOTICES OF MEETINGS.

THE MANCHESTER ASSOCIATION OF ENGINEERS.—Saturday, December 14, the chair will be taken at 6.30 p.m. The undermentioned paper will be read and discussed: "The Development of Reinforced Concrete," by Mr. B. Taylor, A.M.I.Mech.E., M.C.I., Member.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, December 14, at 2 p.m., in the Wood Memorial Hall, Newcastle-on-Tyne, when the following paper will be read, or taken as read: "The Training of Students in Coal-Mining with Special Reference to the Scheme of the Engineering Training Association," by Professor F. W. Hardwick, M.A.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SCOTTISH CENTRE.—Monday, December 16, at 7.30 p.m., in the Rooms, 207, Bath-street, Glasgow, when an Address will be delivered by the President, Mr. C. H. Wordingham, C.B.E.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, December 17, at 5.30 p.m. Papers to be discussed: "Road Corrugation," by Mr. Ernest Leonard Leeming, M.Sc.Tech., Assoc.M.Inst.C.E.; "Investigations in the Structure of Road Surfaces," by Mr. Francis Wood, M.Inst.C.E.; "Notes on Road Construction and Maintenance," by Mr. Thomas Bowyer Bower, Assoc. M.Inst.C.E.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, December 17, at 5.30 p.m., at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2. The following paper will be read: "The Production of Oil from Mineral Sources," by Mr. F. Mollwo Perkin, Ph.D., F.I.C., F.C.S. The chair will be taken by the president, Mr. Charles Greenway.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Tuesday, December 17, at 6.15 p.m., a paper on "Shipbuilding Development in the United States and Canada," will be read by Mr. W. R. Gray and Mr. Edward F. Clarke.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, December 18, at 5 p.m., at 70, Victoria-street, Westminster. Papers to be read: (1) "A Cloud Phenomenon," by Captain C. J. P. Cave, R.E., F.R.Met.Soc.; (2) "Notes on a Meteorological Journal at Wei-Hai-Wei, kept by Commander A. E. House, R.N., 1910–1916," by Mr. C. E. P. Brooks, M.Sc., F.R.Met.Soc.; (3) "The Annual Symmetrical Variation of Certain Elements and a Note on the Choice of Seasons," by Captain E. H. Chapman, R.E., F.R.Met.Soc.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SOUTH MIDLAND CENTRE.—Wednesday, December 18, at 7 p.m., at the University, Edmund-street, Birmingham, when Mr. P. Hunter-Brown, A.M.I.E.E., will read his paper entitled "Carbon Brushes."

THE ILLUMINATING ENGINEERING SOCIETY.—Thursday, December 19, at 8 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, London, when a Summary of Progress in Photometry with special reference to War Problems (tests of parachute lights and flares, self-luminous radio-active paint, integrating photometers, &c.) will be presented, the discussion being opened by the president.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, December 19, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. "Carbon Brushes: Considered in Relation to the Design and Operation of Electrical Machinery," by Mr. P. Hunter-Brown, Associate Member.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, December 20, at 7.30 p.m., at the Royal Society of Arts, Colonel R. E. B. Crompton, C.B., M.Inst.C.E., will deliver his Presidential Address, "What War has done for Engineers and the Part Engineers will have to Play in Reconstruction."

THE JUNIOR INSTITUTION OF ENGINEERS: MIDLAND SECTION.—Friday, December 20, at 7.45 p.m., at the University, Edmund-street, Birmingham, when a paper by Mr. T. E. Dimbleby, entitled "The Manufacture of Cast-Iron Pipes," will be read.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS, (LONDON), INCORPORATED.—Saturday, December 21, at 2.30 p.m., at Caxton Hall, Westminster. Paper by Mr. I. E. Mercer, Assoc. Member, London and North-Western Railway, Crewe, on "The Training of the Locomotive Engineer."

RUBBER SOLUTION FOR WATER-PROOFING DRAWINGS.—Drawings to be used in damp localities, mines, &c., may have to be water-proofed. For this purpose, J. S. Carpenter recommends in the *Engineering News Record* of September 26, 1918, a solution of pure gum rubber, as bought in drug stores, in benzene. He puts a piece of rubber, about 4 in. sq., in half-pint of benzene, contained in a large jar; the rubber swells to three or four times its bulk, and will be ready for use in 24 hours. The solution is then poured into more benzene, so as to yield a thin liquid that will spread under the brush. With this liquid the drawing is coated on both sides. A thicker solution of the same substance is utilised as adhesive to stick parts of large drawings together; the rubber solution is said to be preferable to starch paste, because the joints of the paper do not crimp out of shape and alignment when made with rubber. If the parts may have to be separated again, a rather stiff paste should be taken. The same solution may also be utilised for cleaning dirty drawings; the solution is poured on the drawing, benzene solvent is mopped off, and the remaining film of rubber is rolled up and used as eraser. Rubber bands will not answer in the place of gum rubber, and benzene is more suitable than formaldehyde.

RECENT HARBOUR AND DOCK WORKS, SINGAPORE.

MESSRS. COODE, MATTHEWS, FITZMAURICE AND WILSON, AND MR. J. R. NICHOLSON, M.M.INST.C.E., ENGINEERS.

(*For Description, see Page* 666.)

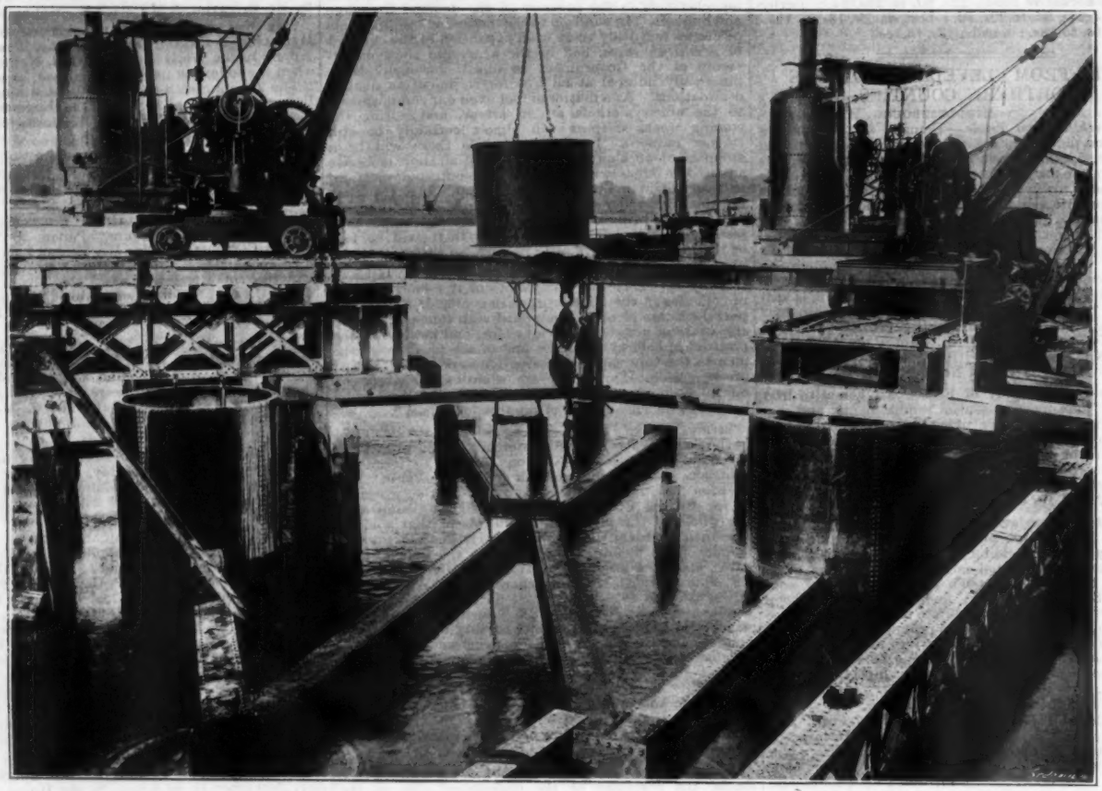


Fig. 39. Wrought Iron Cylinder Construction.

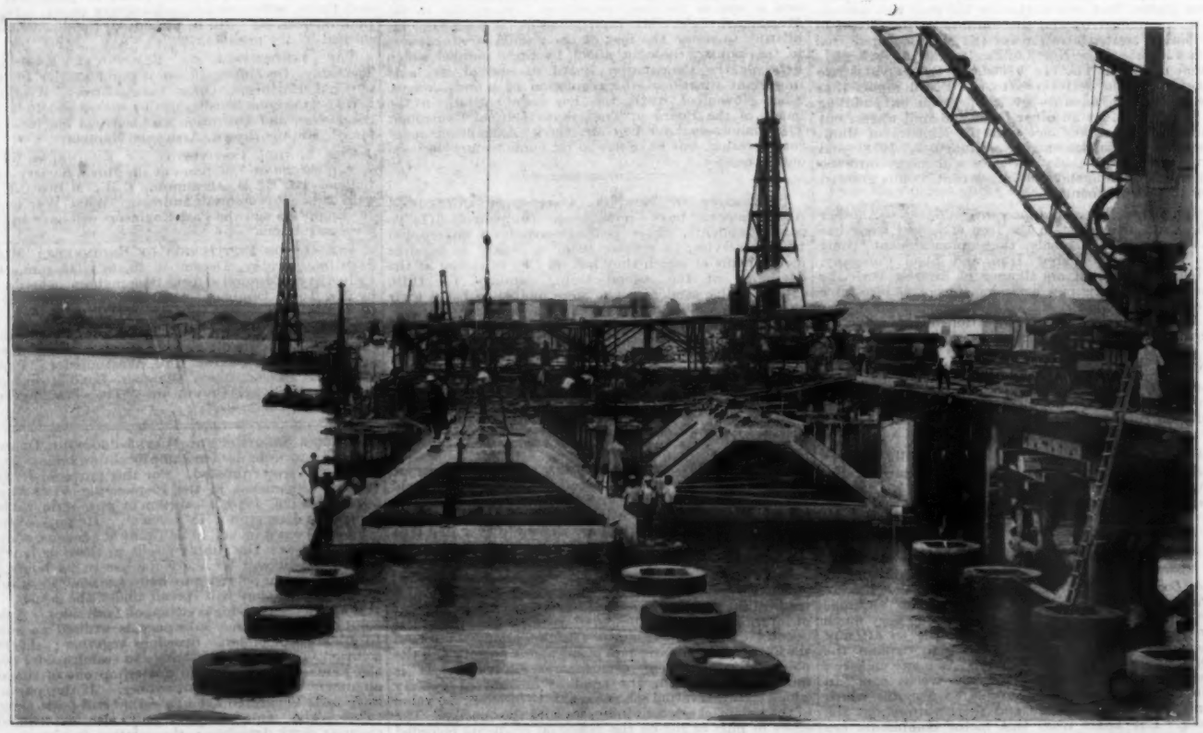


Fig. 40. Reinforced-Concrete Wharf under Construction.

RECENT HARBOUR AND DOCK WORKS AT SINGAPO

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Fig. 19.

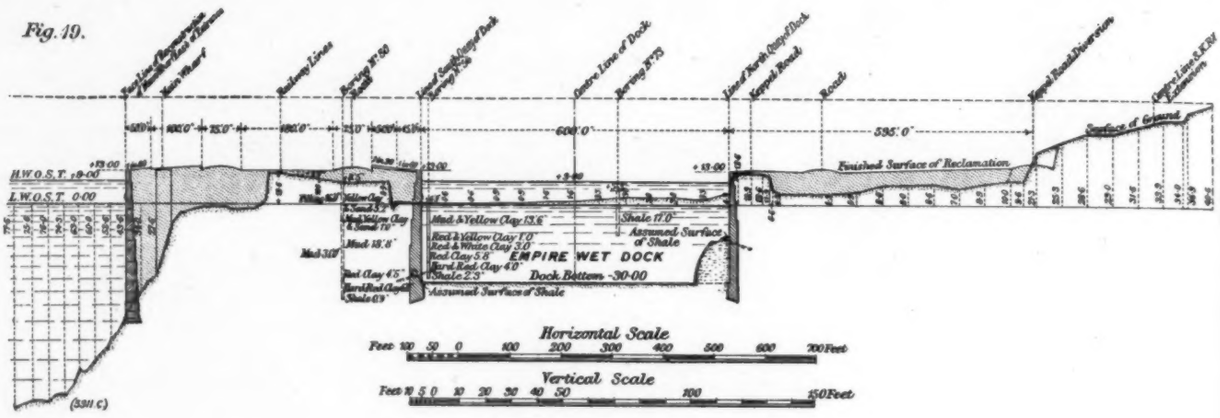
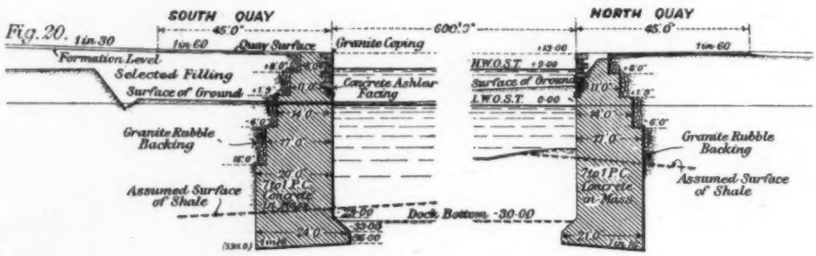


Fig. 20.



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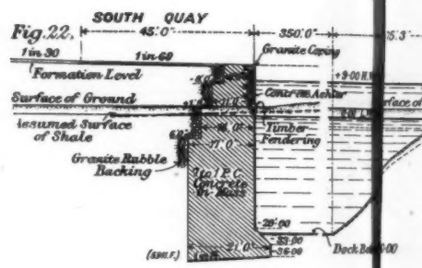


Fig. 28. EAST WALL OF ENTRANCE TO EMPIRE DOCK

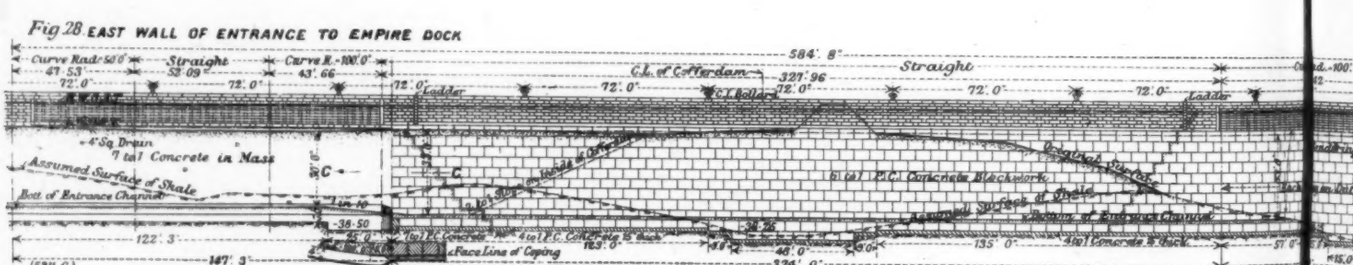


Fig. 29. MAIN WHARF WEST OF ENTRANCE

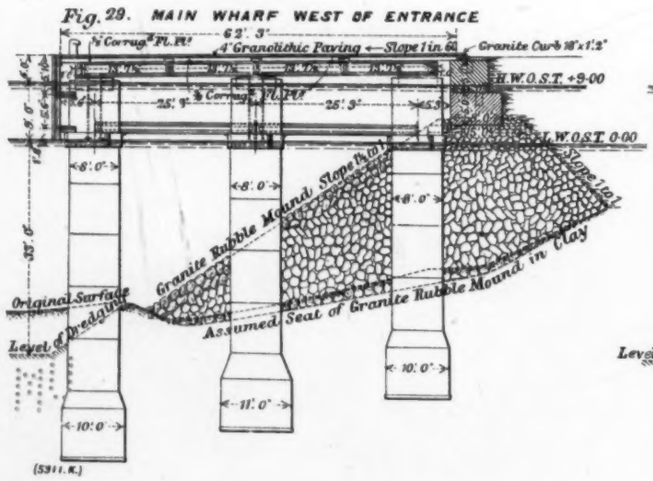
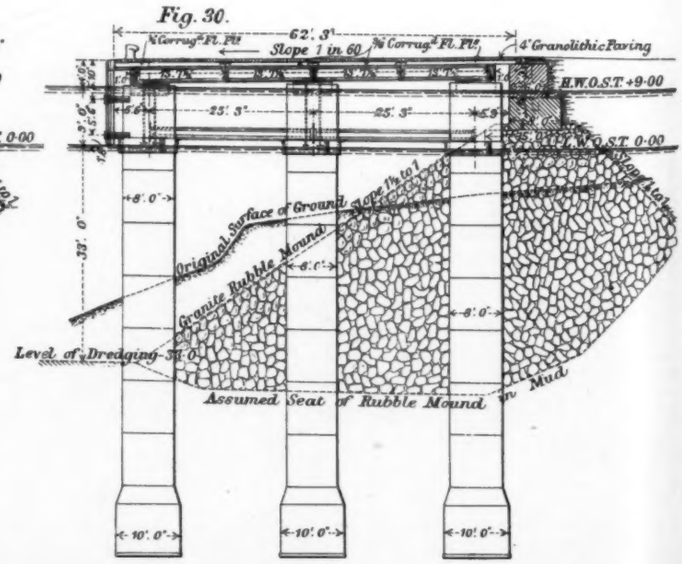


Fig. 30.

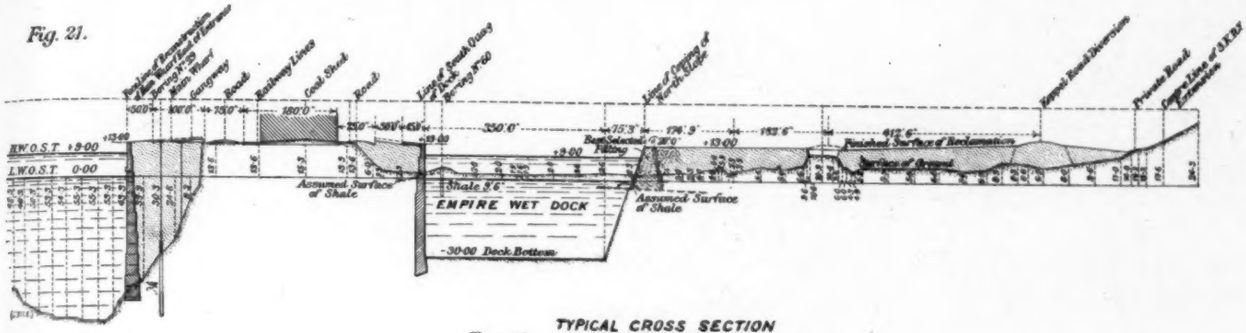

Slope 1 in 60
4" Granolithic Paving
H.W.O.S.T. +9·00
L.W.O.S.T. 0·00
Original Surface of Ground, Slope 1½ to 1
Granite Rubble Mound
Level of Dredging -33'0"
Assumed Seat of Rubble Mound in Mud

APORE, STRAITS SETTLEMENTS; THE EMPIRE WET DOCK.

D WILLIAND MR. J. R. NICHOLSON, MM.INST.C.E., ENGINEERS.

(Description Page 666.)

Fig. 21.



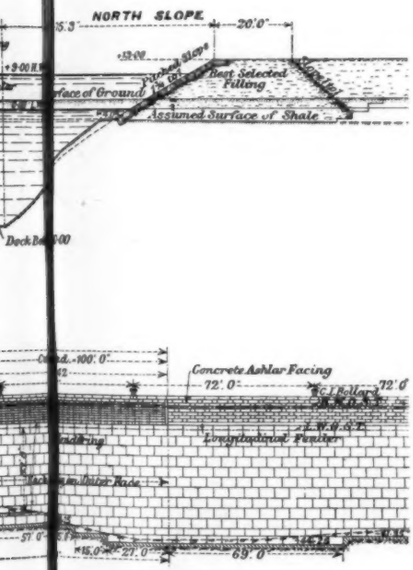


Fig. 23. TYPICAL CROSS SECTION OF DOCK WALLS

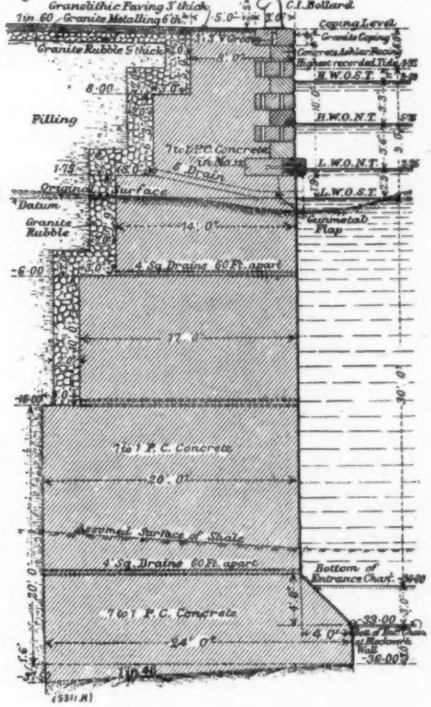


Fig. 24. ELEVATION AT V

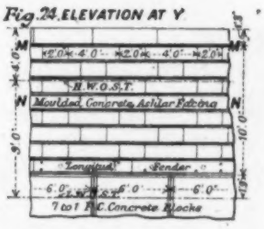


Fig. 25. PLAN AT M.M.

Fig. 26. PLAN AT N.N.

Fig. 27. LONGITUDINAL FENDER

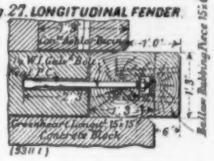


Fig. 31. TYPICAL CROSS SECTION OF BLOCKWORK; WEST MAIN WHARF RECONSTRUCTION
Inclination 1 in 60

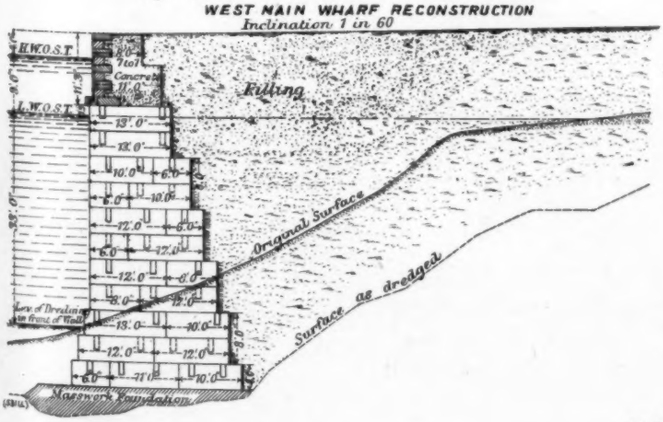


Fig. 32. TYPICAL CROSS SECTION OF BLOCKWORK; EAST MAIN WHARF RECONSTRUCTION
Inclination 1 in 60

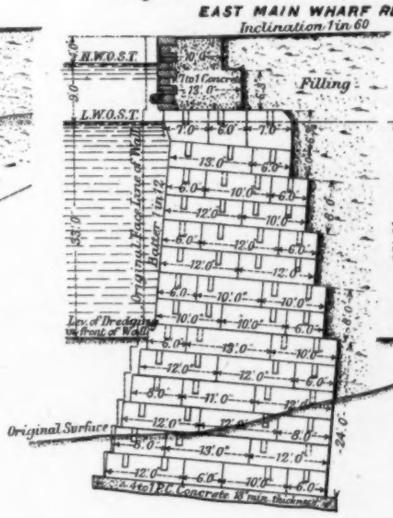
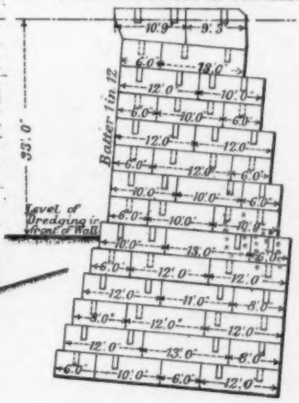


Fig. 33. ALTERNATE BLOCKS IN COURSES



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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

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TELEPHONE NUMBERS—3063 and 8568 GERRARD.

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With a Two-Page Plate of the RECENT HARBOUR AND DOCK WORKS AT SINGAPORE, STRAITS SETTLEMENTS; THE EMPIRE WET DOCK.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 681.

ENGINEERING.

FRIDAY, DECEMBER 13, 1918.

RAILWAY NATIONALISATION.

THE announcement made last week by Mr. Churchill that the Government had decided on the nationalisation of the railways, renders it incumbent on engineers to exert such influence as they possess to prevent a repetition of the mistakes which have occurred on previous occasions when services hitherto administered by private companies have been taken over by the public. It unfortunately happens in the present instance that the possible advantages of nationalisation lie on the surface, and are obvious to the meanest capacity, but it is all important for the future of the transport problem that this "meanest capacity" shall not have the determining voice in the establishment of the new order of affairs. The dangers to be feared as a result of the suggested action are less patent, and are less likely to be generally appreciated, having relation to mind rather than to matter.

Orators have been eloquent in depicting public companies as caring for dividends merely, and nothing for the public. Nevertheless, in actual practice it has been the Post Office, and not the railway officials, which by their neglect and indifference have continued to provide themes for the pen and pencil of our modern satirists. The supercilious young lady who is occasionally found behind the counter of our Post Offices, has had no counter-part in our railway services.

How is it that in this country every great service taken over by the public from private companies has failed to realise the anticipations of the advocates of the change? The telegraphs were purchased with assurances of the most prosperous and profitable future. But few years had elapsed, however, before it had to be admitted that these forecasts had been wholly falsified, and that the service was being run at a loss, although the companies, hampered by restrictions from which the nationalised undertaking was free, had been nevertheless worked at a profit. Much the same has happened with the telephones, and it has not been without interest to observe during the past few days in one column of a journal, violent complaints of the inefficiency of the nationalised telephone service, and in another column rosy anticipations of the economies and improvements to be effected by the nationalisation of our railways. Still a third instance of how far realisation has fallen short of anticipation is afforded by the Metropolitan Water Board.

The telephones, of course, were acquired at considerably below a fair valuation. No credit was given for the imponderables which, as we pointed out last week, often constitute so large a proportion of the value of a going concern. Mere materials were alone assessed, and no allowance made for the capital necessarily expended in pioneering work and in building up the organisation. In America materialism is less rampant than here, and the Inter-State Commerce Commission has definitely laid it down that expenditure, even on an experiment or enterprise which proved unsuccessful, may be fairly taken into account in valuing an undertaking. If progress is to be made, novel schemes and devices must be adventured on, and of these a certain proportion are sure to prove failures; yet their cost remains, notwithstanding, a fair charge on the enterprise.

In the case of the Metropolitan Water Board, it has been freely asserted that the price paid was excessive but, as a matter of fact, the value of the mains alone was nearly equal to the full amount paid. To lay these mains in open country would have cost, under the most favourable conditions, not less than £10,000,000, and the cost of main laying in towns is, as is well known, at least three or four times as much. Hence, the value of the mains alone was nearly equivalent to the full purchase price. To repeat our question, how is it that, in all these several cases, there has been such a wide discrepancy between promise and performance?

Undoubtedly, the main reason lies in the difference in the organisation. The administrative charges tend to be much higher under public than under private control. This is, no doubt, contrary to anticipation, and some would assert, contrary to reason. Reason, however, is of itself but an indifferent guide to truth, and the late Mr. W. B. Bryan, chief engineer to the Board, has stated that the administrative cost of the London Water Board exceeded the aggregate administrative costs of the eight companies which it replaced. According to a recent statement by Mr. Harold Cox, a similar result has followed the nationalisation of the Swiss Railways. He says that the administrative staff is larger than that of the five companies which were absorbed. The real cause of the inefficiency of the public services seems to lie in the fact that these increased administrative charges are all due to an increase in the clerical and statistical staffs, and to a reduction in the departments responsible for creative thought.

An interesting light on this matter is shown by a study of the terms on which the staff of the telephone company was taken over in 1911. Here the rule was laid down that any company official who, by showing initiative and imagination in the company's service, had secured a salary of over 700*l.* per annum, was, *ipso facto* (save in special cases), disqualified for the Government service. So far from "men of push and go" being required, it was to a large extent the men of "push" who had to "go."

In fact, the whole system of organisation was changed. As described by a district superintendent a couple of years after the transfer, all initiative and independence of judgment was suppressed. He knew, he said, exactly where certain matters were going wrong, and how they could be remedied, but if he made any move whatever he would be straightway informed "that the matter did not concern his department." Again, small difficulties which, under the company's management, would be settled locally out of hand, had, under the new *regime*, to be referred to headquarters. The original memorandum received additions at each step of its stately progress from official to official up to the one man who alone had power to settle the affair, trivial though it might be. In many cases, moreover, the memorandum on reaching this official was returned along the same devious path for further data, and had again to retrace its steps to the departmental head before a final decision was taken. The net result was that, instead of the one man who understood the whole of the local conditions settling the matter in half an hour, hosts of officials had all to spend time on it, and weeks might elapse before the final settlement. Obviously, any such system as this must necessarily find employment for a vast army of clerks, so it is easy to see how the administrative costs are increased.

The evil of such a system does not end here, one of its consequences being that the head of the department, who ought to have ample leisure for the consideration of important matters of policy, has practically his whole time taken up with trivialities which, in any efficient organisation, would have never reached him. In this connection, it may be noted that on certain of the great American railways, it has been the custom to relieve

the vice-president of all routine work, so that he and his immediate staff may give the whole of their time to the consideration of new proposals for increasing the effectiveness of the service. In the public services there is nothing analogous to this, and, indeed, the powers even of the heads of departments are often extraordinarily, and indeed ludicrously, restricted.

To sum up, the traditional organisation of our public services has been to discourage initiative and independent judgment on the part of subordinates, and greatly to restrict responsible action in the case of heads of departments. As one result, we have not in any public service "*la carriere ouverte aux talents.*" Able young men, who later on should fill the higher administrative posts, get no opportunity as subordinates for the display of any but humdrum qualities, and are thus not sorted out from the general average. As one result, men competent to supervise the many new undertakings which had to be extemporised during the past five years, were found almost anywhere save in the civil services. Indeed, not the least debt of the nation to the railway companies is due to their work during past years revealing the abilities of the numerous men which the State borrowed to control so many of our war services.

If the question of the nationalisation of our railways is to come up for discussion, it is perhaps as well that it should come now, whilst the memory of this contrast between the results of company organisation and public services organisation is fresh in the public mind. It should make it easier to resist the attempt to establish a new organisation moulded on traditional lines, which all experience shows to have proved singularly unsatisfactory.

No doubt, the German State railways were managed with fair efficiency, even if the staff was mainly parasitic on English or American thought, but an organisation which may be effective in an autocratic country is unsuited to a democratic one. Commenting on this point some eighteen months ago, we observed that whilst the best public service in a democratic country had never, in the whole course of history been as good as the best in an autocratic country, yet, nevertheless, there was reason to believe that the worst in a democratic country had never been quite so bad as the worst in an autocracy. Whether this view can still be maintained depends very much on whether the Bolshevist *regime* in Russia is to be regarded as autocratic or democratic. Our own view is in favour of the first alternative, but some of the most fervent of those who claim to be the apostles of democracy in this country seem ardent advocates of the contrary opinion.

Amongst the advantages claimed for the nationalisation of an industry is that the reserve of stores will be greatly reduced by the greater standardisation which becomes possible. The theoretical benefit of such a change is obvious, but experience shows that it may, on occasion, be purchased somewhat dearly. In the case of the telegraphs, the extensive standardisation of instruments effected on taking over these undertakings from the companies, destroyed competing centres of thought, and the result was to a large extent stagnation. A leading American authority has stated that up till 1870 more than one-half of the important improvements effected in telegraphy originated in Britain, but that subsequently the Post Office simply imported improvements ready made from abroad. On the other hand, we continued as before to make the most important contributions to improvements in submarine telegraphy, which remained under private direction and control. An instructive example of the difference between public and private action in this regard is afforded by the history of long-distance telephony. The principle now in use originated, as is well known, with Mr. Oliver Heaviside, but our postal authorities refused to help him to practicalise his ideas. Some abortive experiments were made, it is true, but not under his direction or control, and the scheme was reported to be a failure. Some years later, Mr. Heaviside's idea was taken up in America, and most ably worked out by Professor Pupin, who in contrast to Mr. Heaviside, received the most generous support and reward from the Western Telegraph Company, with the result that all difficulties were overcome, and the scheme made a practical success. Pupinised cables have, moreover, solved the difficulties of submarine telephony. It will be noted that there are many more systems of State telephones than company controlled systems, yet this great advance was secured by a company and not by a State service.

The sole chance of maintaining the efficiency of our railway services under State control would be that the essential features of the present organisation should not be materially changed. Of course, the ill effects of a change would not be experienced at once any more than they were in the case of the Metropolitan Water Board. In fact, a few years after the transfer the chairman of that Board made a grandiloquent speech, in which he enumerated the many improvements which he claimed were due to the Board, all these, he said, had been made "without one penny cost to the public." As a matter of fact, up to that date the Board was, to all intents and purposes, living on accumulated capital. Every work, whether completed or commenced up to that date, was, in fact, a company scheme worked out before the drastic reduction in the engineering staff. Later on, when really new works had to be undertaken, the weak spot became evident. The staff was inadequate and the few creative minds retained were overloaded with routine.

With the transfer of the railways to the public, there will, undoubtedly, be a strong movement to reduce very largely the higher technical posts. Under mistaken ideas as to the all-importance of abolishing over-lapping, independent centres of thought may be suppressed, with the result that our railways may become purely parasitic for ideas on company-managed lines in other countries. It is of first importance that this tendency should be resisted, though, even if former precedents be followed, the evil effects would not appear at the outset, any more than they did in the case of the Metropolitan Water Board. The best of the old officials—or some of them—would, no doubt, be retained, but if all initiative in subordinates is to be discouraged in accordance with the past traditions of our national services, it will be impossible, as the present leading men die off or are superannuated, to replace them with men of equal calibre.

AERIAL TRANSPORT.

In May last year, the Government appointed a Civil Aerial Transport Committee to consider what steps should be taken at the end of the war to develop aviation for civil and commercial purposes, and to consider to what extent it would be possible to utilise in such undertakings the trained personnel and the aircraft set free on the conclusion of peace. The board was thoroughly representative, including a considerable proportion of technical experts, in addition to representatives of the Dominions and of our principal Departments of State. Their report,* just issued, is, accordingly, of great weight, and contains much of great value, though it has been found necessary in the public interest to suppress a few of the more confidential of the technical contributions. The Committee held that the development of the civilian uses of the aeroplane is of urgent importance. Owing to war conditions, the manufacture of aeroplanes has been developed far beyond all possible demand for peace purposes. It is, however, very necessary to keep the industry in being. Military considerations in themselves are sufficient to show the desirability of maintaining in active operation, a considerable reserve of capacity which would be available for supplying military machines, should the necessity arise. The peace requirements of the Army will, on the most sanguine estimate, be insufficient to absorb more than a small fraction of the possible output, and it is accordingly most important that the development of the industrial and commercial uses of the aeroplane should receive every encouragement from the nation.

Of course, as a freight carrier in normal conditions the aeroplane is hopelessly outclassed by practically every other method of transport. As a mere weight-carrier even an airship is singularly inefficient, although large rigid machines can be made capable of carrying 60 tons gross, or 30 tons disposable load. This latter figure is about nine times as great as the load-carrying capacity of the largest modern aeroplane. For certain services, however, weight lifting is of much less importance than speed. In this connection, of course, a distinction must be made between the speed of flight and the total time of transit between terminals. Aerodromes cannot well be situated in the centres of large towns, and the time taken to tranship and convey either passengers or mails from and to the aerodrome makes the aeroplane incapable of competing with existing means of transport, unless the distance between termini is considerable. Thus, the Committee consider that an aeroplane mail service could not successfully compete with the existing services to places as near London as Manchester or Liverpool. They state that it is now possible to "express" a letter in London at a reasonable hour in the morning, and for this letter to be delivered in Manchester before the close of the business day. This statement would appear to indicate that the reporter who makes it has been unusually lucky in his experience of the Post Office express delivery services. Our own experiences have been much less gratifying. More often than not, the expressed packet has been delivered after, and not before, the normal delivery, and in one case (before the war) a letter expressed in Glasgow before one o'clock in one day was not delivered until mid-day two days later, and, as usual, there was no redress for the inconvenience caused. Accepting, however, this, perhaps, too sanguine view as to the possibilities of our present mail services, the Committee report that although an aeroplane service to Manchester would offer but little gain, a good case can be made out for a mail service to Glasgow via Newcastle and Edinburgh. It is assumed that the flying speed will be 100 miles an hour, and that sufficient mail should be on offer to support one service each way per day. On the "down" service the machine would leave Hendon at 11.15, reaching Newcastle at 2.15. Here mails would be dropped, but the machine would not alight, but continue to Edinburgh, which would be reached at 3.15. Here again, the aeroplane would merely drop the mails without stopping. Glasgow would be reached at 3.45, and the mail distributed in time for a reply by the ordinary train service. The "up" day mail would leave Glasgow at 11.15, alighting at Edinburgh at 11.45. A call to pick up further mails would be made at Newcastle at 12.50, and Hendon would be reached at 3.55. The cost of the service is estimated at 4*s.* 8*d.* per mile, so that the daily expense to a contractor would be about 198*l.* A full load both ways would amount to 32,000 oz., and the contractor's charge to barely cover expenses would be 1½*d.* per oz. The number of letters now passing between the centres named is 260,000 per day. The Post Office suggest that the charge for the aeroplane service should be 1*s.* per oz., but this figure has probably been suggested in order to prevent interference with the established services, rather than in the real interest of the public.

For home use the sole advantage of the aeroplane lies in its speed, but in still undeveloped countries it has some other very important qualities. Requiring no track, the aeroplane can pass over unsettled and desert regions to areas hitherto almost inaccessible. Nevertheless, the speed of the service will, generally, still constitute its principal advantage.

With existing machines the economical limit of distance for a non-stop run is now about 500 miles. Nevertheless the committee have worked out certain routes along which considerably greater flights must apparently be made without alighting. Thus for crossing the Atlantic it is suggested that the line of flight should be from London via Paris, Madrid and Lisbon to San Miguel, one of the Azore islands, distant 775 miles from London. From San Miguel to Newfoundland is 1,346 miles, but the length of this cross-sea passage could be reduced to 1,045 miles by calling at Flores, another of the Azores group. It has been suggested, though the committee hold, without conclusive evidence, that

* *Reports of the Civil Aerial Transport Committee, with Appendices.* [Cd. 9218.] Published by H.M. Stationery Office. Price 9*d.* net.

the Newfoundland fogs will make it undesirable to include this colony in the transatlantic route, and that the line of flight should be from San Miguel to New York. This distance is 2,250 nautical miles, and to make the undertaking feasible it would be necessary to provide mother ships to serve as "sea stations." These ships would be 600 ft. long with an upper deck giving a clear length of 400 ft., and they would, of course, be fitted with wireless and signalling apparatus. With such an arrangement it is held that it would be unnecessary to use sea planes.

The trip from London to Johannesburg now takes several weeks, and a telegram of 100 words costs 8*l.* 10*s.* By aeroplane the trip could be made in under six days, and a letter of, say, 5,000 words, could be conveyed at a cost of 2*s.* 6*d.* The mail to Calcutta would by aeroplane take four days instead of 16 as at present.

In addition to letters there are certain other commodities which the committee consider might stand the high cost of aeroplane transport. Amongst these they mention out-of-season fruits, newspapers, cinematograph films and gramophone records.

The development of passenger traffic will necessarily depend upon the standard of safety achieved. At present accidents are said to be mainly due to the inexperience of pilots and are accordingly largely attributable to the intensive training which has been necessary during the past five years. Engine stoppages, it is said, should not under favourable circumstances imply any serious risk of accident. Even if the *contretemps* occurs over broken country a dexterous pilot generally saves himself and his passengers from injury, although the machine may suffer. Accidents from faulty construction are now far less frequent than formerly owing to the increasing knowledge and skill of designers; although the exigencies of war service make it still possible that a machine may be so overstrained that some part collapses. The cause of fires whilst in flight is being carefully studied, and with the experience and data already obtained it should, it is said, be possible to greatly diminish this danger.

Admitting that the commercial development of the aeroplane is highly desirable, the question as to how this may best be encouraged has been carefully considered by the committee. State aid will evidently be necessary, and the question immediately arises as to whether this should be done by assisting private enterprise or by nationalising the services. The committee do not venture on a definite recommendation on this matter holding it to be a question for the Government. It may be objected that the nation has a right to know what expert opinion is on this head, but very probably nothing like a unanimous report could have been agreed on, since in addition to experts the committee included a certain number of doctrinaires who recommend or oppose policies according as these agree not with the facts of experience, but with certain *a priori* assumptions. The committee have accordingly simply stated the opposing contentions. Those in favour of entrusting the direction to private enterprise assisted by the State, point out that all experience shows that progress is invariably more rapid under this system than under Government direction and control. The arguments in favour of the latter are practically wholly theoretical, the sole statement of fact brought forward being "that transport has always been one of the first fields on which public ownership has shown itself successful, as witness even in Great Britain many successful tramway enterprises." The effrontery of this statement is somewhat startling, as it is common knowledge that probably not one of these municipal tramway undertakings could pay its way were it not protected by law from legitimate competition. Moreover, the development of the electric tramway here lagged far behind that in other countries. Municipalities would neither experiment themselves nor allow others to do so. They waited until foreigners had solved the problems involved, and accordingly a whole field for creative thought was all but closed to British engineers. The reference therefore is peculiarly unfortunate and will appeal merely to the ignorant.

Some interesting figures are given in the report as to the present cost of aircraft. They are as follows:—

	Prime Cost per Lb. of Gross Weight.	Prime Cost per Lb. of Disposable Load.	Prime Cost per Lb. of Commercial Load.
Aeroplane (high speed)	18*s.*	40*s.*	more than 40*s.*
Aeroplane (slow speed)	18*s.*	30*s.*	more than 30*s.*
Airship (rigid) ...	9*s.*	18*s.*	more than 18*s.*

The rigid airship can, without any heavy sacrifice of economy, make a non-stop run of 1,000 miles. It has, of course, the great advantage of being able to stop its engines in mid-air without losing height. On the other hand, it is difficult to handle at termini in stormy weather. It is suggested that the solution of this difficulty may be found in abandoning the practice of housing the machines and instead to merely moor them in the open.

THE INDUSTRIAL FUTURE OF WOMEN.

A REMARKABLE and important Memorial has just been submitted to the Prime Minister by Lady Rhondda "in the name of the Women's Industrial League and on behalf of all women who are compelled or wish to support themselves by working in the manufacturing industries."

Beginning with a short statement of the circumstances in which women were asked to undertake war service in the engineering and other industries, it points out how they entered by hundreds of thousands, and in large numbers were set to do work that up to then had been generally done by skilled men. Though some were trained by the Ministry of Munitions, most of them had to depend for their short industrial education on such training facilities as the works could provide, often improvised without previous experience either of the subdivision of manufacture by which freshly-trained labour can best be employed, or of the most effective methods of instruction. Many women so trained recognise gratefully the loyalty, ability, and patience of their instructors and supervisors; but many others, on the other hand, have had to face avowed or silent opposition. Often, indeed, they were "either left to themselves, without the help they were entitled to expect from their more experienced shopmates, or subjected to actual interference directed to impeding their working or even spoiling their work."

In many shops, moreover, and in many operations, they were not admitted at all. Notwithstanding the agreements and Act of 1915 "there never has been a time from then to now when in some shops in all parts of the country women were not being prevented from doing work that they were doing successfully in other shops." The Memorial instances first some old-established industries, such as sheet-metal working and wire drawing, in which women have been prevented from doing quite simple work and skilled men have been kept on it when, "if they really were skilled, their services were wanted most urgently for work that none but experienced men could do." It refers then to industries, such as aircraft manufacture, that scarcely existed before the war, and in which similar and equally successful opposition was shown, though even the men who claimed to exclude women had themselves as novices to be trained before they became reasonably efficient. In many industries, again, the opposition took the more insidious form of stipulating that the admission of women should be contingent on their receiving "equal pay for equal work," interpreted as meaning equal time worked. In this way women could secure employment on operations which through inferior physical strength or skill they could not do as quickly as men only from firms who would pay them more for an article than they would pay a man; a condition that must inevitably exclude women from the work in the long run, and operates quite differently from the condition that women should receive equal pay for equal output.

The Memorial submits these examples not as exhausting the list of difficulties under which women have worked but as showing sufficiently that their work has "largely been obstructed or altogether prohibited by organised opposition of other workers, by industrial tradition, and by failure to appreciate the industry and capacity of women workers."

It is now, it says, threatened that "even the imperfect toleration that was extended to women during the war should be withdrawn, and that . . . they should resume the condition of helots in which some of them were employed before the war—hewers of wood, provided they do not use an edged tool; drawers of water, provided they do not fit the pipe to the pump." These provisions, it is submitted, are artificial and unjust, disgraceful to a civilised community and thriftless in a prudent one. Experience has shown that "women as a whole have the essential qualities of efficient workers. They keep as good time as men do, their work is as conscientious, their output in the many operations within their strength and experience is as great; even their sickness-rate is as low . . . The present conditions of women's employment, some examples of which we have given, do not do justice to these qualities, and prevent them from being utilised in the national interest."

The Memorial recognises that the Government are doubtless bound by their agreement with the trade unions, but asserts that in the last resort women, who were not consulted when these arrangements were made, are not so bound. Even under these arrangements they may have the freedom of shops in which trade-union restrictions did not prevail before the war, of those that have sprung up during the war and have no *status quo* to which they must revert, and of new shops that doubtless will be erected. "But what women are seeking in industry is not a renewal of strife, but a clear grant to them of their just rights as human beings, the wives and sisters and daughters of the men with whom they will have to work, seeking to help in maintaining and raising the standard of life in the homes that they have in common with men, sharing the men's just obligations and bearing their own."

The claim for employment embodied in the Memorial is expressed as subject to three reservations. From occupations in which women have served during the work only as "a makeshift, valuable while men could not be had, but by reason of inferior physical strength less efficient than men," it is recognised that they must ultimately be excluded, not by agreement or prohibition but by the ordinary rules of economy. If, again, it should appear that there was not enough work for all, women recognise and would wish that they should be restrained from interfering with the preferential employment of discharged service men and of "the men of all-round skill by whom women were trained and helped." But with these reservations women claim "unrestricted liberty to be engaged in any industrial employment and on any operation whatever, provided only that they receive the same pay as men do for equal output." In addition they claim the opportunity of being trained in the most efficient way, and particularly the provision of women instructors on work in which women have proved more successful than men in realising women's difficulties; the same facilities as men for school and university education to fit them for all suitable trades and professions; the same opportunities for promotion to forewomen and the general direction of industry, and full and adequate representation on Government Committees and all public bodies.

These claims are made by women as personal rights, demanded equally by justice to themselves and by national expediency. They make "no separate claim to the many conditions of well-being that are indispensable to the most efficient working. In these they have no interest separate from that of men; and in the interest of all workers alike they await anxiously some more definite information than has yet been published, or perhaps even than has been acquired, as to the precautions by which industrial fatigue can be reduced to its economical minimum, and the hours and conditions of recreation correspondingly extended." The Memorial concludes by expressing "the firm determination of women that their just rights to work in their own interest and in that of the nation must be respected and safeguarded as they have never been hitherto," and asks Mr. Lloyd George for "an assurance that the justice of our cause will be its sufficient recommendation to you and those with whom you act."

In his reply, Mr. Lloyd George expresses his

appreciation of the moderate and comprehensive way in which the Memorial states the case for women in industry, and in particular of its ready and patriotic recognition of the claims of the fighting men and of the skilled men who trained the women to prior right of employment. He expresses his intention, if he is returned to power, to carry out the Treasury agreement of 1915 in such a way that, while the unions shall have no cause for complaint, women will find ample scope for their activities in industry.

The Government, he says, "has never agreed that new industries come under the Treasury agreement." To bring such industries under it, if its restrictive clauses "are seriously believed to be of benefit to the trade unions or any other class in the community," would be "to endow the classes whom the restriction would benefit with the fruit of the sacrifices of the war; a form of profiteering which no body that claims respect and deserves responsibility would willingly touch. These new industries are already extensive, and many will arise in the near future to ensure that our country is more self-supporting than it has ever been in the past; and it will be my care to see that in all these industries no discrimination shall be made against the employment of women in any suitable occupation. In this way, and in those industrial occupations in which women were engaged before the war, opportunities of every sort will be opened for every class of woman worker, and I believe that the real working representatives of organised labour may be trusted when the time comes to see the necessity of utilising in the interests of production and to the best advantage every class of worker available."

On the opposition alleged in the Memorial to have been offered by workmen to the employment of women, Mr. Lloyd George makes the interesting observation that the reference is "not without substance. It is not credible that the trade union leaders who were parties to the agreement went back on it; but leaders cannot always control their followers, and followers sometimes try to become leaders by repudiating the prudent bargains that their leaders have made."

Mr. Lloyd George declares further that he supports the principle of equal pay for equal output, and neither he nor in his belief any enlightened employer could allow or wish women to be used as a catspaw for cutting wages, which at no time is in the interest even of employers, who must desire good production and uniform wages. While pointing out that women already are represented on the appropriate committee in the Ministry of Reconstruction, he admits that more might be done in this direction, and promises that it shall be. He promises that steps shall be taken to ensure women the opportunities they seek of training in schools and universities for the trades and professions in which they can suitably engage.

The Memorial and the Prime Minister's reply outline an attitude towards the continuance of women in industry which on the whole is likely to be approved by engineers who have had experience of women's work under proper conditions of training and employment. That the memorialists should themselves have disclaimed any objection to women being postponed in employment to discharged service men and to the all-round skilled men by whom they have been taught is evidence of a reasonable attitude on which those who have framed their appeal are sincerely to be congratulated. In particular their deference to the all-round tradesmen who have taught them will be appreciated by those who know at what sacrifice these really skilled men, as contrasted with mere machine operators, have devoted themselves to the higher branches of their trade and have abstained from the rich piece-work jobs that the machine operators have enjoyed.

It may be hoped that Mr. Lloyd George's candid statement of the position may do something towards a rational settlement between the Government and the trade unions. No one can justify disregard by a Government of its pledges to any class; and even in the case of the Treasury agreement it would be highly regrettable if it were found to have been avoided by the fact that the consideration for which it was given—the suspension of all restrictions on employment and output for the purposes and period of the war—had never been performed. The agreement is, indeed, unfortunate from the point of view of the country and most of all of its workers because, if the rights that it undertook to restore were in fact exercised, they would be a Pandora's box of disaster to the aggregate body of workers, and before long even to the classes in whose interest they had been asserted. From the point of view of the unions it is scarcely more satisfactory. It restores restrictive customs only in the shops and to the extent in and to which they prevailed before the war. The large numbers of mixed and non-union shops that existed before the war, together with the great new shops and industries that have sprung up during the war and whatever fresh shops may hereafter be opened, will offer unrestricted employment to workers of all kinds. The restoration of these customs for which the Treasury agreement provides could satisfy neither the interests of the country and its industries, nor the claims, in this respect diametrically opposed to national and industrial interests, of the trade unions themselves.

The delusion that the employment of women must result in throwing men out of work is based on a misconception of the present situation, which is at once much more exacting and much more hopeful than is realised by those who seek to limit the supply of labour. It is more exacting because it demands an immediate increase of production, much greater even than the whole production before the war. This is a great enough problem in itself, though the lines on which it can be solved have already been indicated by recent experience. It involves a still more difficult problem in the decision of measures by which the increased output will be so framed as to command a ready sale; and though there is no difficulty in showing the possibility, the means will call for firm, consistent and determined action on the part of manufacturers, and opportune assistance on the part of the Government, for which no precedent can be found in the earlier history of manufacture. To face these real and inevitable difficulties the ground should be cleared from those, such as the conflicts between workers and employers, and between workers of different classes, that serve no useful purpose. Among these one of the most prominent is the decision of the part that women may and must play in future industry; and of all possible ways probably the most mischievous to all parties would be for the trade unions to insist on their pound of flesh.

It is earnestly to be hoped that the interchange of views between Lady Rhondda's League and the Prime Minister may open the way to a more reasonable solution. It is, indeed, of good omen that, beyond the rights of employment and training in suitable occupations which they claim, women should make no claim to separate treatment in respect of any conditions of labour, but on the contrary should expressly seek to make common cause with men. It is a right instinct, too, that in this connection has suggested to them to inquire for news of what is proposed for dealing with the great questions of industrial fatigue. Those who have studied these questions most closely are the most confident that on a sufficient investigation the cause which the women make in common with male workers will be seen to be also the cause of the employers themselves.

HIGH VACUA AND THEIR MEASUREMENT.

The extraordinary high vacua claimed for modern air pumps, and especially for the Gaede diffusion air pump,* make one wonder in two respects. How is it possible, one asks, to produce a vacuum of the order of 10^{-8} mm. of mercury in a pump which works with mercury vapour? And how can we measure the pressures of gases so highly rarefied? Exceptionally high vacua can undoubtedly be obtained with the aid of diffusion pumps, for they are displacing all other means of producing high vacua—except gas absorption by cooled charcoal, which has its own wide field of utility. But how are we sure that the rarefaction is really pushed beyond the limits formerly attainable? The appearance of the electric discharge through vacuum bulbs changes as the gas pressure is reduced; comparative estimates of the gas pressures can be based upon such observations. For actual measurements, however, physicists have practically been relying upon the vacuum gauge which Professor Herbert McLeod, then of Cooper's Hill College, described in the *Philosophical Magazine* in 1874. The idea of this gauge is that a known volume of the gas under test is, by a rising column of mercury, cut off from the rest of the gas and condensed into a smaller space in which its pressure is measured. Pressures as low as 1×10^{-8} mm. of mercury have been determined with the aid of the McLeod gauge, which has indeed served as checking instrument in most of the recent researches we are going to notice. But the apparatus has to be of inconvenient size for the determinations of high vacua; the mercury of the gauge itself contributes an uncertain percentage to the gas pressure to be measured, an allowance has to be made for other gases given off by the apparatus at very low pressures, and this factor can hardly be eliminated by submitting the apparatus to a heat treatment, possible with other gauges.

Other types of gauges, especially mercury-free gauges, have hence been proposed. The Bourdon gauge, in the shape of a glass spiral, was tried by E. Ladenburg and E. Lehmann in 1906. K. Scheel and W. Heuse, investigating high vacua and their production in 1909, separated two chambers, the one connected with the apparatus, the other maintained at constant gas pressure, by a copper diaphragm, and measured the interference bands produced by the deflection of the diaphragm. Studying since 1906 the friction on gases at low pressures by means of vibrating discs, J. L. Hogg found a simple relation between the decrement of the vibrations and the gas pressure. M. von Pirani, 1906, based his method on the determination of the electric resistance of an electrically-heated wire stretched in the gas. At low pressure the thermal conductivity of the gas is a function of the gas pressure; when the volts at the wire terminals are kept constant, the heat loss by conduction through the gas decreases as the pressure is lowered, and with a bridge arrangement the pressure can be measured by keeping constant either the temperature of the wire, or the current flowing through it. The Pirani gauge was simple, but did not prove very sensitive; C. F. Hale improved the sensitiveness, and the gauge is particularly suitable for lamp measurements, but it has especially to be calibrated for the particular gas in the bulb, since the thermal conductivity of a gas depends upon its nature. The molecular gauge of S. Dushman, 1915, is the outcome of Langmuir's researches on thermoionic currents in high vacua. The gauge consists of a glass bulb in which a metallic disc is rotated by producing a rotating magnetic field outside the bulb; a second disc carrying a mirror is suspended within the bulb above the first disc. Good work has been done with this gauge also in low-temperature research; the mechanism is elaborate, however, and though all its parts bear temperatures up to 300 deg. C., the relatively large masses of metal are not desirable for high vacua. In 1916 O. E. Buckley proposed an ionisation gauge, consisting of a kathode (Wehnelt kathode or incandescent filament), an anode and a collector between these electrodes; he determines the ionisation of the gas produced by the electrons given off by the filament which is charged to several hundred volts, his actual gas pressure measurement depending upon the ratio of the collector current to the anode current. The method can be modified in various ways. In the most recent paper on the Production and Measurement of High Vacua (*Physical Review*, July, 1918), J. E. Shrader and R. G. Sherwood, of the Westinghouse Research Laboratory, state that finding the Buckley gauge, which has to be established for each gas and vapour, not very sensitive nor very constant in its readings, they had devised a new form of the Absolute Manometer, which Professor Martin Knudsen, of Copenhagen, most fully described in the Annalen der Physik, volume 32, pages 809-842, 1910. This gauge has much been used of late.

The paper quoted, it will be noticed, was written before the days of the diffusion pump, but later

* Described in Engineering, August 25, 1916, page 169; and January 28, 1917, page 83.

communications followed, and Knudsen dealt in 1917 already with the effect of the tension of the mercury vapour in mercurial pumps. Knudsen directly measures the forces of repulsion set up by the molecular bombardment between two parallel plates of unequal temperatures which are mounted close to one another in the rarefied gas. These forces determine the total pressure due to any gas or vapour present in the space under examination, and Knudsen himself speaks of them as radiometer forces, as it has been known since 1874, that it is the bombardment by the molecules of the residual gas in the Crookes radiometer which turns the vanes. Though there is quite a literature on the radiometer, it does not appear that the radiometer forces were ever utilised for quantitative pressure measurements, and the radiometer hardly lent itself to such measurements. For this purpose accurate temperature measurements would have been required, and there was, as Knudsen points out, uncertainty as to the exact way in which the kinetic laws should be applied to the radiometer. Maxwell considered that there would be very little effect between the central parts of two parallel discs, because the temperatures varied uniformly between the discs; stress would only arise from inequality of temperature in the gas near the edges of the discs. Johnstone, Stoney and Fitzgerald suggested that there must also be a disc effect, and not merely an edge effect. Knudsen sides with the latter.

Gas molecules rebound from a warm wall with a greater velocity than from a cold wall. When there is temperature equilibrium between the molecules and the wall (solid or liquid), the direction in which the molecular rebound is independent of the direction of incidence, and the average velocity of the molecules remains unchanged, according to Knudsen. But when there is no temperature equilibrium, i.e., when the molecules oscillate between two parallel plates of unequal temperature, both the direction and the velocity of the rebound are changed. As long as the distance between the two plates is very small compared to the free path of the gas particles, the force of repulsion between the two plates depends only upon the gas pressure and the temperature difference; when the latter and the force of repulsion are known, the gas pressure can be deduced by a simple formula. This formula is $p = 2\,K/\left(\sqrt{\frac{T_1}{T_2}} - 1\right)$, where p is the gas pressure in dynes per sq. cm., K the force of repulsion in the same unit, and T_1 and T_2 indicate the absolute temperatures of the two plates. For small differences of temperature the formula may be simplified into $p = 4\,K\,T_2/(T_1 - T_2)$. Knudsen deduced these formulae from the kinetic theory and confirmed them by experiments with hydrogen, oxygen, air, carbon dioxide and mercury vapours, and for gas pressures of less than 0·003 mm. of mercury, or less than 4 or 5 dynes per sq. cm. The formula does not hold for pressures higher than 0·003 mm. When a constant c is introduced, so that the numerator of the first formula becomes 2 Kc (leaving out the denominator), c converges towards the value 1 as the gas pressure approaches zero. With increasing pressures c grows exponentially, and c is (equal pressures presumed) smaller for hydrogen than for the other gases, and c also varies but slightly with the distance between the plates and the temperature; in the case of oxygen the relations appear to be somewhat less simple. Knudsen's experimental proof followed three lines: (1) At ordinary temperature his gauge agreed with the McLeod gauge which, as already stated, indicates the pressure of the gas together with the pressure of the mercury vapour at the respective temperature; (2) the pressure of the gas was varied by introducing small measured volumes of the gas into the apparatus, the pressure variations agreeing with the McLeod readings and with Mariotte's law; (3) a little mercury was admitted into the apparatus, the air evacuated, and the mercury then condensed by cooling the glass walls; the gauge readings went down in accordance with the diminution of the mercury vapour pressure.

In its simplest form the Knudsen gauge consists of an electrically-heated strip or plate of platinum, in front of which, at a distance of about 1 mm., a piece of foil is suspended as vane; the deflections of the vane are observed by the aid of a mirror and telescope. To study edge effects, the plate was cut up into several narrow parallel strips, or the plate was given the form of a copper cylinder with horizontal axis, surrounded by a longer concentric copper cylinder; the apparatus was also arranged like an electrometer, two vanes, each covering half the plate, being used, the one in front, the other behind the plate. Very good results were also obtained with a water-jacket apparatus; there is an inner glass tube in which a piece of mica is axially suspended as vane; the tube is sealed into a wider glass tube, itself surrounded by a water jacket, and the tubes are connected with the vessel to be evacuated. In this case the warm gas molecules in contact with the outer tube reach the vane through a rectangular slit provided in the inner tube. The temperature difference $T_1 - T_2$ was varied between 8 deg. and 250 deg. in the various experiments. The Knudsen gauge of Shrader and Sherwood, which we mentioned above, is more elaborate. It is a glass bottle with short neck, 9 in. high, 2 in. diameter, containing a C-shaped glass rod from which the parts are suspended. The heating strip is of platinum, 0·018 mm. thick, 7·5 mm. wide, 18 cm. long, and is folded so as to form a flat horseshoe, about 7 cm. long; it is kept straight by tungsten wires and is connected by platinum wires to the wires leading to the potentiometer. The moving vane is a plane, rectangular frame of aluminium foil, 0·0076 cm. thick, 0·5 cm. wide, the outside dimensions of the frame being 4 cm. by 3 cm.; an aluminium wire prevents warping of the foil, which carries a mirror; the suspension is by a tungsten wire of 0·0005 in.; we give the dimensions in millimetres, centimetres and inches, as in the paper. The distance between the strip and the vane, about 1 mm., can be adjusted from outside by means of a magnet. The mirror of the vane is a small piece of platinised glass, baked at 500 deg. C. In some experiments the platinum strip was heated up to 525 deg. C. absolute. In comparative tests against a McLeod gauge of 750 cub. cm. capacity, the two gauges agreed within 10 per cent. for pressures of 3×10^{-5} mm.; the lowest pressure measured by Shrader and Sherwood was 2×10^{-5} mm. Silver mirrors first used did not stand the heat treatment to which the gauge was submitted.

Electric heating of the strip offers the advantage that resistances can be substituted for the temperatures in Knudsen's formula, and that temperature measurements, needed for the water-jacket apparatus, are not required. Shrader and Sherwood give the formula in electric terms, and they also describe an improvement of the mercury diffusion pump which seems to deserve notice. As regards the theory of the diffusion or condensation pump and the rebounding of molecules from hot walls, about which Knudsen and Langmuir are not in accord, we must refer to our previous articles.

NOTES.

Spontaneous Explosion of the Charcoal in Liquid-Oxygen Containers.

The use of liquid air and liquid oxygen in the chemical and mining industries, in the latter case as blasting agent, has much spread on the Continent during the war. The liquid air is generally transported in double-walled vessels (vacuum-jacket vessels) which are made of metal rather than of glass, and the jacket space is usually charged with some superior charcoal in order to maintain the vacuum during the gradual emptying of the vessel. Several recent cases of explosion of such vessels have been investigated by Professor Lothar Wöhler (*Chemiker Zeitung* of October 5, 1918). He found that the explosions occurred because the inner metal of the vessel had been broken, and the liquid oxygen had been absorbed by the charcoal at an explosive rate. All the vessels in question had been supplied by one Austrian firm, and Wöhler failed to produce explosions by breaking, with the aid of a tool, either the walls of vessels of the Sprengluft-Gesellschaft, of Charlottenburg, which are charged with a charcoal of the highest absorptive power, or the walls of other vessels, charged with ordinary charcoal. The analyses demonstrated that the charcoal of the faulty vessels was rich in both zinc and iron. When iron chloride was added to ordinary charcoal, this did not turn explosive. The superior charcoal of the company named became explosive, however, when containing 3·5 per cent. of iron; when containing only 3 per cent. or 2 per cent. of iron, the access of oxygen gave rise to a violent combination, but not to an explosion, and smaller percentages of iron had no deleterious effect. It was thus clear that an explosion would only occur when the charcoal was not only impure, but also very highly absorptive. The presence of ammonia in the charcoal made no difference in the observations. Addition to the charcoal of substances like colophony, naphthalene or powdered pyrite, substances which would favour electric excitation by friction, did not render a safe charcoal explosive either. The iron was not present as metal; but probably as iron oxide; addition of powdered iron oxide did not do any harm either, whilst, on the other hand, extraction of a contaminated charcoal with hydrochloric acid removed the dangerous constituent. It seems thus certain that explosions are only to be feared when a very highly absorptive charcoal contains a certain amount of iron and possibly also of other impurities. Finely divided phosphorus, *e.g.*, is dangerous; but that was to be expected, and contamination of the charcoal with phosphorus is hardly likely. The iron oxide seems to act catalytically as oxygen carrier, and a small quantity of charcoal, 0·1 gramme, proved sufficient to cause an explosion, provided the conditions above stated were fulfilled. There have also occurred a few cases of explosions of blasting cartridges containing soot or sawdust and liquid oxygen. These accidents are of a different nature; they occur during the tamping of the bore holes when the oxygen prematurely gains access to the combustible which the mechanical friction has heated.

Carbon Piston Rings by the Lavaud Centrifugal Machine.

If it be true—we do not wish to question the statement—that the United States now require 200,000,000 piston rings annually, especially for automobiles and aeroplane machines, and that one notable firm alone cannot do with less than 16,000,000 of these rings per year even in normal times, one can understand that there will be demand for a centrifugal machine which can supply up to 20,000 rings per day. Centrifugal machinery for making castings is as old as some of our engineers of the present day. Packing rings were not wanted by the thousands in the old days, however, and the machine which the Standard Piston Ring Company, of Newark, New Jersey, has adopted, is an ingenious example of modern automatic machinery. The inventor, Mr. D. Sensaud de Lavaud, is described as a Brazilian in *The Iron Age* of October 3 last, which characterises the machine as a development of the Lavaud centrifugal iron pipe casting machine, said to be in use in France and Canada. By the old method piston rings are either cut off from tubular castings, or more frequently are cast in moulds; an output of 420 rings per day would probably be good work in the latter case. The Lavaud machine carries three revolving moulds on three horizontal radial arms protruding from a vertical central standard which can itself be turned about its axis in order to let the moulds pass successively through their cycle of operations. Each mould is built up of a series of rings alternating with discs of thin boiler plate in such a way that a series of grooves is formed; each groove constitutes a mould for one ring. The parts are held together by two end discs and by external bolts, and the whole chamber is mounted on a driving disc attached to the standard, so as to make 1,200 revolutions per minute about a horizontal axis. The chamber can also be pulled outward over its arm to allow the ladle, which has the shape of a horizontal scoop, fixed on the machine baseplate, to enter the axial hollow of the chamber. When inside the mould, the ladle is turned by hand so as to empty the metal into the mould; the molten iron is thrown against the circumference of the mould, and the rings are formed. At the next moment the mould revolution is stopped, the mould pushed back to the standard again, and the standard is turned through 120 deg. into the second

position. All these movements are effected by the successive advances and reversal of one lever. When the mould arrives in the second position, boys pull off the bolts, the parts of the mould—still loosely held together—open out, and the rings drop into a basket; the mould is pulled off, attached to a wheel which rotates the parts in a cooling tank, and the chilled parts are then reassembled and bolted again by the aid of a double-acting pneumatic machine; the mould is afterwards remounted on the standard. The rings have meanwhile been sent through an annealing furnace, consisting of a refractory vertical cylinder, a horizontal section of which is heated by an oil burner, and an external shell of sheet iron; the rings are fed in at the top, pass through the hot zone at 1,900 deg. F. (controlled by a pyrometer), and drop out below at the rate of 1,200 rings per hour. The rings are now ground to the proper internal diameter; this is done in a double-acting machine which takes groups of 20 rings. The drive of the standard is by electric motor. The iron is melted in a cupola which is to be replaced by an electric furnace; the ladle is lined with refractory material, and other provisions are made for rendering all parts easily replaceable. The machine, for 18,000 or 20,000 rings per day of 8 hours or 10 hours, is attended by 11 men or boys. Rings are made in diameters ranging from 1½ in. up to 8 in., and it is said that rings of 30 in. or 40 in. could be made. Piston rings must possess a certain springiness and mechanical strength; tests made at Columbia College as to these features are stated to show the superiority of these rings over ordinary moulded rings. One would have liked to have some information about average numbers of defective rings; too rapid cooling of the metal might spoil a whole casting or part of it.

Cranes Revocation Order.—The Minister of Munitions has issued an Order dated the 6th inst., revoking the Cranes Order 1916 which provided that no person might sell or supply any steam, electric, hydraulic or hand-driven cranes without a permit.

Motor Engines and Vehicles Renovation Order.—The Minister of Munitions has issued an order dated the 6th inst., revoking the Order of 1917 which prohibited any person from carrying out without a permit any work connected with the manufacture or erection of any new or unused motor internal combustion engine designed or adapted for mechanical traction, or of any new or unused motor cycle, motor chassis, motor waggon, or traction or other motor vehicle propelled by mechanical means.

A Flight from Cairo to Baghdad.—The aeroplane has already begun its task of forming a link between African and Asiatic countries where railway communications are as yet either non-existent or not of the best. On November 29, Major-General Salmond, R.A.F., Brigadier-General Borton, R.A.F., and Captain Ross Smith, A.F.C., with two air mechanics, started off from Cairo in a Handley Page machine, and arrived at Damascus the same afternoon. Next day they started again from Damascus at 7.25 a.m., and flew to Baghdad, which they reached at 3.30 p.m. on December 1. Thus in three days they visited the three countries, Egypt, Syria and Mesopotamia, and linked up the two great Asiatic Expeditionary Forces of the British Empire.

Use of Benzol in Motor Vehicles.—The Board of Trade desire to draw the attention of owners of motor vehicles to the fact that owing to the cessation of hostilities considerable quantities of benzol are now available for use as motor fuel, and the ordinary motor spirit licences can be used for the purchase of benzol as well as petrol. After January 1, the Petrol Control Department will be prepared to issue special supplementary licences available for the purchase of benzol only. These special licences will authorise the purchase of a quantity of benzol exceeding by 50 per cent. the quantity of petrol which would have been allocated on an ordinary motor spirit licence. In accordance with the announcement made by the Board on November 15 licence-holders should apply for increased allotments of motor spirit after January 1, and state whether they desire the supplementary allowance to be granted on an ordinary motor spirit licence or on a special benzol licence. Licence-holders to whom supplementary licences available for benzol only are issued will be given the option of converting their original licences, wholly or in part, into licences available for benzol only. New applicants may apply for either an ordinary motor spirit licence or a special licence for the purchase of benzol only. Further information may be obtained upon application to the Controller, Petrol Control Department, 19, Berkeley Street, London, W. 1.

LITERATURE.

Colour in Relation to Chemical Constitution. By E. R. Watson, M.A., D.Sc., Professor of Chemistry at Dacca College, Bengal; Temporary Research Chemist with British Dyes, Limited. London: Longmans, Green and Co. [Price 12*s.* 6*d.* net.]

A little consideration of the phenomena of light and colour makes one comprehend why philosophers generally begin their teaching by insisting that the thing as it is may have little in common with the thing as it appears. Light in itself is invisible; we see the object on which light falls. When the student is shown that the beam of white light may be decomposed into many colours, he is warned not to take that "decomposition" literally, and that the glass of the prism may have impressed properties on the light which were not originally in the beam. Thousands of people may admire a rainbow at some definite moment. Yet no two of them see the same rainbow, any more than two persons, standing in front of a mirror, perceive the same image, and the rainbow has no more real existence in front of us than the image has behind the mirror. We are quite aware that our senses are deceiving us; but we have nothing else to guide us. We read with pathetic interest that Plateau was blind when he studied the fascinating phenomena of soap bubbles, as was F. Huber when he wrote on the wonderful social life of bees in their hives, and that Beethoven was nearly deaf when he composed some of his greatest music. But every musician is expected to be able to "read" music; neither Plateau nor Huber was born blind, and they had the eyes of friends to rely upon.

When we see the dull grey wings of a moth suddenly flash up in brilliant steel-blue or watch a drop of oil which, spreading on a puddle of water, makes the water iridesce in beautiful colours, we do not forget that the colour sensation is very illusory. Iridescence appears merely to be evidence of a peculiar surface condition. All the same we regard colour as being in many cases something as characteristic of a substance and as inherent in it as its taste and smell and weight. We believe to understand that the sky is not blue for the same reasons that an ink or the crystals of copper sulphate are blue. We may say that sulphur is always yellow, the leaves are green, though we know that colour, like other properties, changes with conditions. Just on account of the transitory character of colour, however, there seemed to be ground for hoping that some day we might discover how colour is connected with the other properties of an element or its compounds. When chemists learned to prepare artificial dyes which possessed the colours and properties they wished to impart to them by introducing new groups of elements into them and by modifying their constitution, that hope was strengthened. Fifty years of strenuous work in this field have hardly brought us nearer the realisation of such hopes.

That is also the impression we gain from the perusal of Professor Watson's "Colour in Relation to Chemical Constitution." Since most of the hypotheses concerning the problems have been worked out in connection with researches in organic chemistry, which is moreover his own speciality, Professor Watson begins with that division of chemistry, and he deals with the colours and spectra of inorganic compounds and of the elements themselves only in his last chapter. We will comment on the latter features first, however. Most elements are colourless, their compounds likewise. Even the elements of the iron group, comprising chromium, cobalt, nickel whose compounds are pronouncedly coloured, have themselves merely metallic grey colours. But gold is yellow, copper red, oxygen faintly blue when liquefied and indigo blue as ozone, and Professor Watson finds unmistakable regularities in the colours of the oxides, chlorides and sulphides of the elements when arranged in their natural groups according to the periodic law; colour develops in any group as the atomic weight increases. Carey Lea, indeed, considered that his periodic series of the elements according to the colours of the ions was more perfect than Mendeleieff's table. When we observe flame colours we notice that the alkali metals become more distinctly red as we proceed with rising atomic weight from potassium to rubidium and caesium; in the alkaline earth metals, calcium (reddish), strontium (intense red), barium (green), the order seems rather reversed.

But direct eye observation and flame coloration are crude criteria. When we examine the spectra, we find the bright emission lines and dark bands distributed all over the spectrum; the unquestionable regularities of the series of lines and bands in the same and in related elements have long been studied; we now believe we can account for the simplest spectra of hydrogen and helium; but we cannot claim much more. It is there that organic chemistry has come to our help, though in that case the study has to be limited to absorption spectra, since flame temperatures and electric discharges would destroy the compounds. Naturally the absorption was first studied in the visible spectrum, and when photographic spectroscopy revealed the existence of the ultraviolet, that end of the spectrum received almost preferential attention. That was a great step in advance, not merely because it widened the field. The production of visible physiological colour is due to the occurrence of absorption in the visible spectrum and is more or less an accidental circumstance influenced by the limitations of sight. Red glass and red ink appear red because they transmit red rays absorbing other shades; but selective absorption is generally not restricted to one particular portion of the spectrum. A band in the ultraviolet would be invisible and non-existent to the eye, unless revealed by photographic or other means. Now we shall presently see that the "weighting" of molecules with heavier elements frequently tends to shift the bands towards the red. Thus a colourless substance, apparently free of selective absorption, may be coloured in certain derivatives; unaware of the existence of ultraviolet bands in the parent substance we might attribute the colour of the derivative, really connected with the displacement of the bands, to a modification in the constitution favouring a certain colour. Hence the great importance of the ultraviolet. That reasoning obviously should apply to the infra-red as well, and in a stronger sense even; for the visible spectrum is limited to the range 0.45 μ to 0.75 μ, the ultraviolet takes us down to about 0·25 μ, whilst infra-red rays have been traced nearly up to 400 μ; 500 μ would be half a millimetre. Yet long after Rubens and others had vastly extended the extreme red end of the spectrum, chemists considered that they might almost disregard the infra-red spectrum in colour studies. During the last ten years a reaction has set in, and undue prominence has possibly been given to the infra-red.

Without exposing the general principles of light emission and absorption and of colour, which are incidentally dealt with, Professor Watson, writing as a chemist, starts with the different hypotheses as to colour and constitution which grew up with the development of synthetic colouring matters. Many of these suggestions have proved of considerable technical utility and they retain their value; exceptions to all the rules have multiplied, however, and none of them cover the whole ground. As early as 1868 Graebe and Liebermann pointed out that coloured organic substances became colourless on the addition of hydrogen, and they suggested that colour depended upon the existence of double bonds between oxygen, nitrogen and carbon, which the addition of hydrogen turned into single bonds. Thus blue indigo is reduced by hydrogen to its "leuco-compound," white indigo; the rule seemed to hold until Scholl found, in 1903, that hydrogen reduces the greenish-yellow anthraquinone-azine to the deep blue indanthrene. In 1876 O. N. Witt proposed that the "chromogen" molecule must contain a certain grouping of atoms ("chromophores," NO_2, N = N, CO, &c.) which impart the potentiality of colour, to which must be added certain salt-forming radicles ("auxochromes," OH, NH_2, &c.) to bring out the colour; the chromogen itself may be colourless. Next came Nietzki with the already-mentioned suggestion that colours are "deepened" by the introduction of radicles of high atomic weight. Most people speak of bright yellow as deeper than pale yellow (mixed with more white), whilst colour chemists unfortunately

call both blue and red-deeper colours than yellow; their sequence of colour-depth is green, blue, violet, red, orange, yellow, according to Professor Watson, these colours being complementary to the spectrum colours taken in the usual order red to violet. Of general theoretical interest was H. E. Armstrong's suggestion of 1888 that dyestuffs either contained the "quinonoid" grouping or could assume it by tautomerism. The quinonoid structure requires a benzene nucleus, two atoms of which, in the ortho or para (not in the meta) position, are attached to the same atom outside which is thus held by a double bond (or certain modifications of this structure). Tautomerism (dynamic isomerism) means that certain reversible changes easily take place in the grouping of the colours within the molecule, *e.g.*, that an oxyn atom joined to one carbon may go over to another carbon and return again so that two isomers co-exist in the same solution, whilst two ordinary isomers would similarly differ as to the grouping, but each would be stable.

Modifications of these hypotheses were proposed by Baeyer (Armstrong), H. v. Liebig, H. Kauffmann (auxochromes), Schütze, Piccard and J. T. Hewitt, the latter three modifying Nietzki's views. Hewitt asserted that colour deepened with an increase in the length of the conjugate chain of alternate double and single bonds, whilst Professor Watson and Meek believe that dyes which are quinonoid in all their possible tautomeric forms have a "deep" colour, no matter how simple the structure and how small their molecular weight, and further that the period of the light vibration is proportional to the length of the conjugate chain which is reversed, *i.e.*, in which double and single bonds change places. In the case of polygenetic dyes and mordants the depth of the colour evidently does not increase with the molecular weight of the metal with which the dye combines; alizarin, *e.g.*, is yellow in alcoholic solution, gives orange dyeings on tin, red on alum, maroon on chrome, and is purple in alkaline solution. Here as in the violurates of Hantzsch the depth of colour seems to increase with the increased electropositivity of the metal; this Professor Watson and Meek ascribe to the increased electrolytic dissociation of the salt formed by the auxochrome at the end of the conjugate chain. Hantzsch has, further, in some cases isolated several potassium salts of different colours (yellow, red, green, violet) of the same phenyl compound, and he regards each of these salts as a "chromo-isomeric" modification of the same compound or, if the number of available isomers should be insufficient, as mixed crystals of isomers. In his latest papers Hantzsch maintains that mere ionisation—most dyes are supposed to display their strongest colour when ionised—and mere replacement of hydrogen by an alkyl radicle do not change the absorption, and that changes in absorption must go together with changes in the chemical constitution; from this point of view solvents are either true (indifferent) solvents, or pseudo-solvents which combine with the substance and cause absorption-changes. These papers were published after Professor Watson had completed his manuscript, which is quite up to date. We miss all allusion to phototropic phenomena, however. Certain crystals temporarily assume other colours when exposed to certain radiations, and these phenomena are, by one school of chemists, ascribed to peculiarities in the chemical constitutions of these compounds.

Passing to the nature of the vibrations causing absorption and colour, Professor Watson notices first the hypothesis (1904) of E. C. C. Baly and Desch that the absorption was not due to either of the two tautomeric modifications, the ketonic or the enolic, $-CH_2-CO-$ or $-CH=C(OH)=$ "but rather to the process of tautomerism by which the two forms were continually changing, the one into the other"; the point might have been put more clearly. Like the other hypotheses, this one failed because it could neither explain cases of absorption, in which tautomerism seemed to be excluded, nor the absence of absorption in cases of unquestionable tautomerism. The hypothesis was hence modified by Baly, A. W. Stewart and others. Watson finds the explanation in the reversal of the chain of conjugate double and single bonds, which he likens to the pulses travelling up and down a goods train when it is being shunted. One looks here for something like a discussion of the vibrations of atoms and of molecules and of light scattering; but there are only incidental references to these points and to X-ray examination of crystals, followed by a chapter on the electronic theory of vibration after N. Campbell, 1913. Campbell at that time concluded that the intense vibration bands represent the vibrations of electrons and not of entire atoms or groups of atoms, and that each band is due to one vibrating particle per molecule. But Campbell had only studied a very small number of dyes. Meek showed in 1917 that in some dyes several electrons were concerned, and one asks with Professor Watson why bands are in many instances so broad and indefinite and asymmetrical if due to one electron only.

These theories of Baly are further discussed in the chapters on absorption in the infra-red and on fluorescence. The latter chapter refers to the views of Hewitt, R. Meyer and Stark (all substances possessing selective absorption are fluorescent), but it is mainly a critical review of the theories of Baly upon which we commented in our issue of April 19, 1918,* when Professor Baly discoursed on Absorption and Phosphorescence before the Royal Institution. According to Baly the frequencies of the various bands of a substance are all integer multiples of a fundamental vibration frequency in the infra-red. The infra-red has undoubtedly been neglected; the quantum theory and its extension with respect to colour by Eucken and Bjerrum, from which Baly starts, are not to be disregarded, and the regularities traced and predicted by Baly are certainly striking and must have a significance. But one does not understand the leading ideas. Hartley already discovered over 300 lines in the ultraviolet of benzene, and we agree with Professor Watson that in order to account for these and other lines as multiples of the fundamental vibration and for their displacements in solutions of different solvents and concentrations, &c., Baly has elaborated his theory to an extent that he can explain any line in any position as some multiple of the fundamental, reducing the fundamental if necessary.

Professor Watson, early in his book, interposes a chapter (his third) on the methods of recording absorption bands and determining their intensity, and there are many pages of diagrams and photographs of absorption curves and also, of course, of constitutional formulæ in this volume of 197 pages. The book, excellent in many respects, would have gained if matters such as absorption and colour, the influences on colour of solution, ionisation, solvents and mordants, and the reasons for assuming molecular, atomic and electronic vibrations had separately been discussed and not treated as incidentals. But Professor Watson writes as a chemist, as we said, and he had to keep within the frame of the "Monographs on Industrial Chemistry" to which this volume belongs. He does not sum up in favour of any theory, though he may consider that his own views supply the summary that can at present be given. We do not complain about the absence of a summary. As long as physicists can supply the chemist only with electronic models for his simplest atoms, speculations on the electronic vibrations of highly complex organic compounds are premature. There was, on the other hand, a decided want of a book on colour and constitution, and Professor Watson's volume, which is based on lectures given at Leeds University in May, 1917, certainly reads very well. There is an immense literature on the subject, and no recent treatise. The 1916 report of the British Association Committee on Absorption Spectra and Constitution of Organic Compounds (Sir J. J. Dobbie, Professors Baly and Stewart) occupies 55 pages, although it consists merely of the most concise literature references.

Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry. Vol. ii, 1917. London: Harrison and Sons, W.C. 2. [Price 6s. 6d. bound, post free.]

THE first volume of the Annual Reports on Applied Chemistry had to be brought out last year† without the projected sections on Fibres and Dyeing, Metallurgy, Electrochemistry and Sugar, which were not ready in time. The second volume now before us, which has expanded from 325 octavo pages into 537 pages, embodies these sections. The first, welcome section on Plant and Machinery is new, and there are changes in the compilers of several of the sections. Nominally on the year 1917, the reports very properly notice the last few years, and the new divisions in particular may be said to go back to the beginning of the war.

Progress through the war, Professor J. W. Hinchley, of the Imperial College of Science, writes in the first section, has nowhere been more active perhaps than in chemical engineering. Continuous processes have supplanted familiar discontinuous processes; superior stoneware is made in the country, injectors, cocks, &c., being trued up with the aid of diamond tools; filter presses are made in enormous numbers and with accurate frames and plates; multiple-effects evaporators are worked with small temperature differences (2 deg. to 5 deg. instead of 30 deg. C.); the new salt-cake furnaces of Six and Guttmann require only ¼ h.p. per ton-day output and one attendant for six or more furnaces; and by an ingenious method of supporting the cores the tubular evaporators of the Kestner film evaporator for corrosive liquids are built in cast-iron tubes 15 ft. long, 2 in. bore, and not in sections with sockets of wrought iron when the life of the evaporator depended on the life of the sockets. On some points Professor Hinchley might be more explicit. He speaks of a new substitute for stoneware pipes, centrifugal pumps, &c., which must be able to withstand great stress, but he merely gives the name "ceratherm," which is not mentioned in the section on Refractories. There is further a nameless "dynamic impulse steam trap," about which we should have been glad to learn more. Other novelties are described, *e.g.*, as a very successful cement, the inventors Charee, Hunt, Holley and Webb being named in a footnote. We should prefer to have the names in the text. That is a matter of taste. But we must deprecate the practice of a few other compilers, notably Mr. A. J. Hale in the section on Electrochemistry, of quoting in long strings of footnotes new inventions and also papers merely by the numbers of the patents and by literature references, without stating any names. How is one to find information if a number, especially also in the case of badly accessible German patents, should be misprinted? We do not overlook that in most instances additional references to the Journal of the Society of Chemical Industry are given. But the name frequently affords valuable guidance, and the attention of the compilers might have been drawn to this undesirable feature of a report which is to facilitate further study.

The new section on Fibres, Textiles, Cellulose and Paper, by Mr. J. F. Briggs, of the British Cellulose and Chemical Manufacturing Company, also contains a few nameless patents. We are rather surprised to read that in South Australia cereal straw should be considered the only material immediately available for paper-making; some ferns yield a very tough fibre, but those fibres will have been tried, no doubt. In America wood pulps remain the chief raw materials; the Imperial Institute finds certain South African grasses suitable, provided they could be worked up in the county of origin; shipping the grass does not look profitable. There is no mention of the sulphite wood-pulp industry rising in Scandinavia. The section on Bleaching, Dyeing, Printing and Finishing, by Mr. S. H. Higgins, is also new; it is supplementary to the preceding section and to that on Colouring Matters and Dyes which Dr. J. T. Morgan keeps in hand. Mr. H. A. Auden, who reports on Alkalis, Acids and Salts like last year, mentions that the Lonza A.G. in Switzerland makes ammonium sulphate from the sulphite, but does not say that the company has started the manufacture of alcohol from calcium carbide and acetylene. The Precht process is interesting because it manufactures ammonium sulphate from magnesium sulphate and ammonia under pressure. The rich potash deposits near Motembo, in Cuba, turn out to be very poor, we see. Mr. Auden's few remarks on radium and argon might just as well have been

* A misprint in the fifth line from the bottom of this article—the word "But" should read "that"—was corrected in the issue of April 26.

† See ENGINEERING, September 7, 1918, page 260.

omitted; one would hardly look for them in that section, moreover.

We learn from the section on Glass, Refractory Materials, Ceramics and Building Materials, drawn up by Mr. W. J. Rees, of Sheffield University, that much good would result to the industry if some scheme for the pooling of technical knowledge could be arranged. We were under the impression that the Society of Glass Technology and other bodies had been more successful in this respect. There is no reference to boron nitride in this section, nor to boron at all in the volume according to the indices, which are deficient, however. Both the sections on the Metallurgy of Iron and Steel, by Mr. C. O. Bannister, and on the Metallurgy of the Non-Ferrous Metals, by Mr. G. Patchin, of the Sir John Cass Technical Institute, are new. Mr. Bannister might have alluded to oxygen in his comments on Johnson's researches on foundry iron, and he is not up to date on the occlusion of gases; Mr. Patchin does not mention detinning, and his references to aluminium alloys are inadequate. Chemists—we mean this in general—do not appear to consult the report of the Alloys Research Committee and of the National Physical Laboratory. New is also the section on Electrochemistry, by Mr. A. J. Hale, of Finsbury Technical College. We wish we had proofs of the improvements of dry cells, of which he speaks—without giving names, as we stated already. The Cottrell process of electric precipitation, somewhat novel to this country, should have received more attention in the volume. In the index it is mentioned once under the entry of electric separation, a term used by Mr. Hale and insufficiently explained by him. The name Cottrell occurs once in the index; Mr. Bannister speaks of the application of the process in the precipitation of blast-furnace dust, but the references are old, and the precipitation of potash dust is not especially alluded to. Mr. Hinchley states that in one concentration plant for sulphuric acid 25 tons of acid are daily recovered from fumes by the process; the index does not notice this fact.

Two sections are devoted to oils. Mr. W. J. A. Butterfield deals with Mineral Oils. He is certainly not too severe in his remarks on the confusion prevailing in the nomenclature of oil; his new suggestions dispense with the use of the terms benzine and gasolene, which may mean anything; he also criticises the Rittman cracking experiments which were conducted on a big scale but apparently not by men of sufficient experience, and have not turned out a success; we had our doubts, when describing the experiments. Messrs. E. R. Bolton and C. Revis report on Oils, Fats and Waxes, industries which are likely to take a very important development. It is very satisfactory to learn that research on india-rubber has been very active. According to Mr. H. P. Stevens, the world's production of plantation Para (from the east) has risen from 69,000 tons in 1914 to 215,000 tons in 1917, whilst the outputs of wild rubber (mainly Brazilian, 38,000 tons in 1917) and of other sorts of rubber (12,000 tons in 1917) have almost remained stationary. The section on Sugars, Starches, and Gums, by Mr. T. H. P. Heriot, of the Royal Technical College, Glasgow, is the last novelty we have to notice in this annual report. We should add that Professor J. S. Brame this year deals with Fuel.

An Introductory Treatise on Dynamical Astronomy. By H. C. Plummer, M.A. Andrews Professor of Astronomy in the University of Dublin and Royal Astronomer of Ireland. Cambridge University Press. [Price 18s.]

Those who have studied the problem of disturbed elliptic motion in the elementary treatises of Godfrey and Cheyne on the Lunar and Planetary Theories respectively, eked out possibly by a tutor's MS., will admit that this work marks a very considerable progress in the preparation of advanced text-books. The view is more consecutive and penetrating, the examination more thorough, and the grasp more certain. It is no compliment to Professor Plummer's work to compare it with such old-world standards, but in the absence of other English authorities such comparison is inevitable. The influence of Euclid, or of the Principia, led the authors mentioned to continue the practice, though not retaining the form, of distinct propositions, each more or less complete in itself. Such a plan was not calculated to enable the student to obtain that complete survey of a large and fascinating subject, which we imagine it is the author's object to keep before the student. The plan fostered the vicious habit of mastering such portions as, being of convenient length, were likely to be required in the schools. Here the matter is presented in a logical order, and the student having the necessary mental capacity and due preparation in the manipulation of symbols, is put in possession of a complete scheme, whose interest is perennial, and whose mathematical discipline is excellent. The author has considered the student's position and needs, he has placed himself in the position of a tutor, and has considered throughout a helpful method of presentation, that without sacrificing the logical arrangement makes the path easy to find and to follow. This assistance starts from the first, when we find our old friends Kepler's Laws treated in a novel manner, that invests them with a new interest. By novel is meant novel to us, because we admit to our shame that we had not read Halphen, Bertrand and other authorities. This confession is made in order to call attention to an important and welcome feature, the incorporation into a text-book of results that lie latent in the voluminous transactions of learned societies. This treatment adds a freshness and an approach to originality which it is difficult to give to a well-worn subject.

The object of the treatise is to trace the development of convenient and precise methods for calculating the orbit of a body moving round a central mass in a conic of any eccentricity, and the effect of the introduction of a third body in the case of elliptic motion. The problem is not limited to motion in the solar system, but is extended to embrace the discussion of the orbits of both double stars and of spectroscopic binaries. From the problem of two bodies the student is introduced to the Planetary Theory, including the consideration of special and secular perturbations. The chapters on the Lunar Theory especially illustrate the author's main purpose of enabling the student to master more easily the technical details encountered in special treatises. The number of inequalities to which the Moon's motion is submitted make the complete investigation of her path one of great intricacy, and only a low order of approximation is worked out, a plan, however, that indicates the nature of the principles involved, principles that may easily be overlooked in attempting to follow the complete but complicated machinery that accuracy unfortunately demands. Owing to the part the moon plays in precession and nutation these phenomena are discussed at some length, in a section that has rather the appearance of an excrescence.

"Numerical applications find no place in this work." We regret the limitations which have made such a decision necessary. The mathematician who with toilful study has furnished himself with tools and succeeded in erecting a serviceable scaffolding, finds here a use for the machinery he has laboriously collected, but is debarred from putting the coping stone to his work. At many points in his career, he must have thought that subtlety and elegance were to be their own reward, and here he might have found a practical application of much that appeared obscure or ornamental. It is some compensation to know that the author regards arithmetical technique with respect. If he does not calculate the elements of an orbit, offers no worked examples of special perturbation, or does not attack the final test of applied theory—the prediction of the co-ordinates of moving bodies in the form of an ephemeris—he so far recognises the ultimate task of analysis that he leaves all formulæ finally in a shape suitable for numerical calculation. Professor Plummer feels so acutely the need of impressing the student with the importance of calculation, that he adds a final chapter on interpolation, mechanical quadratures, and some other numerical processes that come before the practical computer. And he tells us that "few parts of a theory can be regarded as complete till they are reduced to a numerical form. This process, which often demands immense labour . . . is just as essential as the manipulation of analytical forms."

THE GERMAN IRON INDUSTRY DURING THE RECONSTRUCTION PERIOD.

A Rhenish-Westphalian report says, that there is no reason to expect that, with the cessation of the war, prices in the iron market will move in the opposite direction to, and at a similar rate with, the movements during the war. The shortness of materials and the fact that there was no official control on the prices had the result that until the spring of 1917 the upward move of the prices for iron products, in harmony with those ruling for raw materials, kept rising almost without any break. This was more especially noticeable as regards some finished products, which were particularly scarce—for instance, thin plates, for which something approaching fancy prices was paid. When in the spring of 1917 another rise in price was mooted, in spite of works making immense profits declaring the current prices to be unremunerative, official interference and control set in, the authorities endeavouring to stop this movement, at least to some extent, through the medium of fixing maximum prices. The consequence of this step was, that the extremely high quotations of the spring of 1917 have only been raised in isolated cases, where the works could show the necessity of a rise on account of a material increase in the cost of production. In this way ores, pig-iron and coal were still raised in price several times. As regards the finished products the demand of the works, at the beginning of each period of delivery, for higher prices has been negatived by the authorities. In view of all the conditions there is much likelihood of a pronounced shortage of raw materials for some time to come. The whole question of future development hangs upon the extent to which ores and other raw materials can be supplied, such as are essential for normal working. In this connection there is very grave apprehension. Even now there is much delay and stoppage in the matter of a regular supply of fuel, which has already led to reduced working and which ere long may compel some works to shut down. Some iron works certainly have sufficient supplies of ore to allow of reduced working of the blast furnaces for some months to come without any fresh supplies, and Seegerland and other inland ore districts can, of course, help to make up for the discontinued supply of ore from other quarters, especially Lorraine. But it is more than questionable whether there is enough rolling stock available for the transport of material both to and from the works. The result will in that case be, that the output will only be in the market in limited quantities, which entails the temptation of raising the prices. In the meantime, the present maximum prices will remain in force, even if the system of emergency licences has been done away with.

Coal Gas for Motor Vehicles.—The Gas Traction Committee has arranged a Gas Traction Section in connection with the forthcoming British Scientific Products Exhibition to be held at Manchester from December 27 until the middle of January. The Executive Committee of the Automobile Association has therefore decided, by the special desire of the Gas Traction Committee, to postpone the closing date for receiving entries for the association's 1,000*l.* competition for the best method of using coal gas as a motor car propellant, until January 31, 1919. The conditions of the competition, also entry forms, may be obtained from the Secretary, Automobile Association and Motor Union, Fanum House, Whitcomb-street, London, W.C. 2.

The Visibility of Radiation.—The *Astrophysical Journal* of September last contains an article by E. P. Hyde, W. E. Forsyth and E. F. Cady, of the Nela Research Laboratory, General Electric Company, Cleveland, Ohio, on the "Visibility of Radiation," an account of an investigation undertaken with the object of deciding whether, in comparing the relative brightness of radiations of different colour hues, the flicker method is preferable to the older method of direct comparison by the photometer. The experiments were carried out with the aid of a Lummer-Brodhun spectrophotometer. The light from a tungsten lamp was focussed on the slit of this photometer; the light of a second tungsten lamp was similarly focussed on a rotating sector-disc, and the brightness of this second source was varied by adjusting the volts at its terminals until the two images on the diagonal surface of the spectrophotometer cube appeared of equal brightness. The range from $\lambda = 0{\cdot}5\,\mu$ to $\lambda = 0{\cdot}62\,\mu$ was investigated on 50 steps each of from $0{\cdot}002$ to $0{\cdot}005\,\mu$ to avoid differences in hue as much as possible. Full sets of measurements were taken by twenty-nine different observers, of the Nela Laboratory and of the Bureau of Standards, and the deduced relative visibility data were then averaged in a somewhat novel way. It must be pointed out that the different observers often differed very widely in their figures; as they were all observers of experience, however, no figures were rejected, and the averages were based upon all the observations. The conclusions drawn are that in ordinary photometric comparisons involving differences of colour the older method of direct comparison is adequate if a sufficient number of observers be employed to secure an average eye. The relative candle-power values so found differ appreciably from those obtained with the flicker method; the latter method gives a somewhat broader visibility curve, and the differences are ascribed mainly to the fact that the flicker photometer seems to assign too much weight to the red end of the spectrum, so that the relative candle-power of a lamp, expressed in terms of its power at a lower temperature, is found to be smaller than that obtained by the method of direct comparison.

THE SUPPLY OF SINGLE-PHASE POWER FROM THREE-PHASE SYSTEMS.*

By Professor MILES WALKER, D.Sc.

SUMMARY.

THE various methods of supplying single-phase power are considered under the five heads enumerated below. Of these, No. (4) and No. (5) are dealt with at length in some detail. Under No. (4), phase balancers are divided into stationary and running balancers. A qualification is added to Steinmetz's statement on stationary balancers. It is shown that the elimination of the alternating component of the power does not necessarily bring about a "balance of the phases," as defined. The correct method of balancing the phases in the case of an electric furnace working at 0·7 power factor is developed for both choke-coil balancer and condenser balancer. Running balancers are classified under five subheadings (*a*) to (*e*), according to the method used of overcoming the impedance drop in the windings. The graphic diagrams of the different types are given, and the merits and drawbacks of these balancers discussed.

Under head No. (5) a new type of balancing transformer is described. A calculation of a balancing transformer for feeding a 400-kw. electric furnace is worked out. The figures obtained on the tests of the machine at no load and at full load are given.

PRESENT DEMAND FOR SINGLE-PHASE POWER.

The advantages of three-phase power distribution over the single-phase systems in vogue twenty-five years ago are so generally acknowledged that a very large proportion of the electrical power stations of the world generate alternating current in three phases. There are, however, some purposes for which single-phase current is to be preferred, as, for instance, in high-voltage alternating-current traction systems. Here the single-phase trolley wire and resulting connections are so much simpler than the double trolley wire and the adjuncts of a polyphase motor, that some engineers prefer a single-phase system. The successful operation of this type of traction in different parts of the world has created a considerable demand for single-phase power.

Another purpose for which single-phase power is required at the present time is the operation of electric furnaces. There can be no doubt that, putting aside all considerations of convenience of electric supply and looking at the objects to be attained merely from the metallurgical point of view, the single-phase furnace has much to recommend it. Nevertheless, on account of the great objections raised by the suppliers of electric power to the unbalancing effect of a single-phase load upon their three-phase systems, the polyphase furnace is in much more extensive use in this country than the single-phase furnace.

In view of the very extensive use that will be made of electric furnaces for steel manufacture in the future, it is important to see what can be done to minimise the objection of the suppliers of electric power to a single-phase load.

METHODS OF OBTAINING SINGLE-PHASE POWER.

Where single-phase power must be supplied for any specific purpose, we have a considerable choice of methods of obtaining it.

(1) Single-phase generators driven by prime movers.
(2) Three-phase generators constructed so as to give single-phase power.
(3) Motor-generator sets.
(4) The taking of single-phase current direct from one of the phases of a three-phase supply system, and the use of a balancer for balancing the phases.
(5) A rotating balancing transformer, which absorbs the balanced three-phase power in one winding and supplies a single-phase load from an independent winding.

(1) SINGLE-PHASE GENERATORS DRIVEN BY PRIME MOVERS.

Where the single-phase load is near some source of mechanical power, such as a large steam generating station or a water power, it is comparatively a simple matter to install single-phase generators that can be run independently of any other generators in the station. This has been done in the case of several single-phase traction systems; for instance, in the case of the New Haven and Hartford Railway, where special single-phase steam turbine-driven generators supply the trolley wire direct at 11,000 volts.

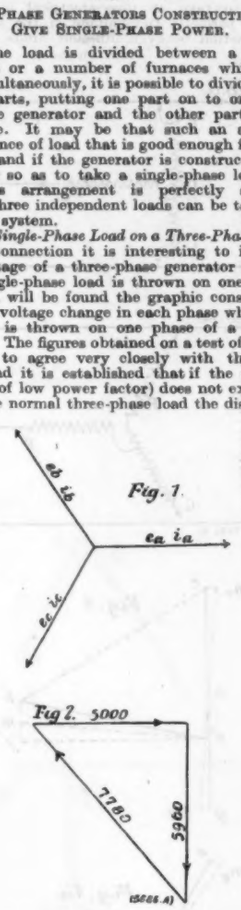
The main objections to the single-phase generator are the following: The cost for a given output is higher than for a three-phase generator; for instance, the cost of a 25-cycle single-phase generator of 5,000 kw. capacity, running at 1,500 r.p.m., would be about 30 per cent. higher than that of a three-phase generator of the same characteristics. This is partly because the single-phase output from a given frame is less than the three-phase output, and partly because a single-phase generator must be provided with a very heavy and well-constructed amortisseur on the field magnet, the cost of which is a considerable item. Secondly, the efficiency of a single-phase generator is considerably lower than that of a three-phase generator of the same rating. This is caused partly by the higher iron losses due to the single-phase armature reaction, and partly by the loss in the amortisseur and the metal surrounding it. The actual percentage by which the efficiency is thus reduced cannot be stated without reference to particular machines, because so much depends upon the proportions of iron and copper and upon the details of the design. Looking through a number of quotations that have been made by a manufacturing firm, the author finds that it is not uncommon for the guaranteed efficiency of a large single-phase generator to be 1½ per cent. to 2 per cent. lower than that of a three-phase generator of the same general characteristics.

It is in general inconvenient to provide special single-phase generators to supply the load, especially when the load is some distance away from the power station.

(2) THREE-PHASE GENERATORS CONSTRUCTED SO AS TO GIVE SINGLE-PHASE POWER.

Where the load is divided between a number of locomotives or a number of furnaces which are not started simultaneously, it is possible to divide the whole into two parts, putting one part on to one phase of a two-phase generator and the other part on to the other phase. It may be that such an arrangement gives a balance of load that is good enough for practical purposes; and if the generator is constructed with an amortisseur so as to take a single-phase load without injury, this arrangement is perfectly satisfactory. Similarly, three independent loads can be taken from a three-phase system.

Effect of Single-Phase Load on a Three-Phase Generator.—In this connection it is interesting to inquire how far the voltage of a three-phase generator is disturbed when a single-phase load is thrown on one phase. In Appendix I will be found the graphic construction for finding the voltage change in each phase when a single-phase load is thrown on one phase of a three-phase generator. The figures obtained on a test of a generator are shown to agree very closely with the theoretic figures; and it is established that if the single-phase load (even of low power factor) does not exceed 20 per cent. of the normal three-phase load the disturbance to the voltage is inconsiderable. An instance of this kind is found at Bradford, where single-phase furnaces of 400-kw. capacity are thrown on and off three-phase mains without causing a noticeable unbalancing of the voltages.



Single-Phase Armature Reaction.—The ratio of the field ampere-turns on single-phase short-circuit to the field ampere-turns on three-phase short circuit is also given in Appendix I. This is in the neighbourhood of 0·7, but depends upon the pole arc and the efficiency of the amortisseur.

(3) MOTOR-GENERATOR SETS.

In some cases where power companies have refused to connect a single-phase load on to their systems, motor generators have been installed. A motor generator for this purpose may consist of an induction motor direct connected to a single-phase generator; or a synchronous motor may be used to drive the single-phase generator, and in this case the set may be used for improving the power factor of the system by over-exciting the synchronous motor. For general convenience of operation this method is entirely satisfactory; the consumer has complete control over his own voltage; the power factor on the three-phase side can be adjusted at will; and the maximum demand can be kept within bounds, notwithstanding the heavy currents that may be drawn from the single-phase generator at times of short circuit. The main drawbacks to this plant are the high first cost and the poor efficiency. Owing to the low efficiency of the single-phase generator, especially when built with heavy armature conductors for large currents, the efficiency of the whole set is usually very poor. A 500-k.v.a. size has an efficiency of about 85 per cent.

(4) SINGLE-PHASE CURRENT FROM THREE-PHASE SUPPLY WITH BALANCER.

In order to secure a higher efficiency than can be obtained from a motor generator, and a better specific use of the material employed, a number of different types of balancers have been proposed for balancing a three-phase system that would otherwise be thrown out of balance by a heavy single-phase load. These may consist either of stationary apparatus, such as choke coils or condensers, or of running machines, which may be either synchronous or asynchronous.

What is Meant by "Out of Balance."—Before considering the various types of balancers, it is necessary to define more exactly what we mean by a three-phase system being out of balance. The generating plant in a three-phase power station might conceivably be so large and its impedance so low that quite a large single-phase load might be thrown on one phase, and yet the voltage might remain practically undisturbed; so that from the consumer's point of view the system might be considered in balance. It may even be that, through some slight dissymmetry in the winding of the generators, the voltages at no load are slightly unsymmetrical; and that when the single-phase load is thrown on, the balance of the voltages becomes perfect. We see that it is necessary to distinguish between unbalanced currents and unbalanced voltages; and in considering voltages and currents their phases and wave-forms are important as well as their virtual values.

Let us take first a three-phase system in which the voltages and currents are of pure sine wave-form. Let the voltages measured from the star point to the terminals be:

$$e_a = E_a \cos(\omega t - a_a),$$
$$e_b = E_b \cos(\omega t - 2\pi/3 - a_b),$$
$$e_c = E_c \cos(\omega t - 4\pi/3 - a_c).$$

Let the currents in the three legs be:

$$i_a = I_a \cos(\omega t - \phi_a),$$
$$i_b = I_b \cos(\omega t - 2\pi/3 - \phi_b),$$
$$i_c = I_c \cos(\omega t - 4\pi/3 - \phi_c).$$

Then the voltages are in balance when:

$$E_a = E_b = E_c \quad . \quad . \quad . \quad . \quad (1)$$

and

$$a_a = a_b = a_c \quad . \quad . \quad . \quad . \quad (2)$$

In a mesh-connected system the angles between the voltage vectors are dependent upon the values of the voltages, because the vector sum of the voltages must be zero. In this case (1) and (2) are not independent. We may, however, consider the star-connected case where the phase angles are independent of the voltages.

The currents are in balance when:

$$I_a = I_b = I_c \quad . \quad . \quad . \quad . \quad (3)$$
$$\phi_a = \phi_b = \phi_c \quad . \quad . \quad . \quad . \quad (4)$$

In a three-phase star-connected system not provided with a fourth wire, the phase angles of the current are dependent upon the values of the currents, because the vector sum of the currents must be zero. Therefore conditions (3) and (4) are not independent. We may, however, consider the perfectly general case where a fourth wire is provided and where the currents and angles are independent.

If a symmetrical generating system has impedances of finite value, any departure from the conditions of balance in the currents causes a want of balance in the voltages. On the other hand, if the impedances in the generator and line are unsymmetrical, the voltage at the consumer's terminals will be unbalanced even when he draws currents that comply with conditions (3) and (4) above. If the voltages at the terminals of consumer S are unbalanced (owing, let us say, to an unsymmetrical load drawn by consumer U), a load of symmetrical polyphase machinery having small impedance, when put in circuit by consumer S, will have the effect of bringing the voltages more nearly into balance. This is due to the fact that the line supplies unbalanced currents to S's symmetrical apparatus, so that even if the effect were almost to balance the voltages S can justly complain that his load is unbalanced. He would, in fact, have unequal heating in his windings, owing to the unsymmetrical loading of U's apparatus. Meanwhile, the central station engineer might be congratulating himself on the fact that his voltages and currents were very nearly balanced. If, therefore, we wish to make a complete statement of the want of balance on any system, we must be precise as to the part of the system under consideration, stating whether the voltages are unbalanced as to amplitude or phase, and whether the currents are unbalanced as to amplitude or phase. This is all on the assumption that the voltages and currents are of pure sine wave-form; if not, there are of course very many more ways in which the system and parts of the system may be unbalanced.

Returning to the case of pure sine wave-forms, there is another way of considering the unbalanced load. In a single-phase circuit in which the voltage is $e = E \sin \omega t$ and the current is $i = I \sin(\omega t - \phi)$, the expression for the power is:

$$p = \tfrac{1}{2} E I \cos\phi - \tfrac{1}{2} E I (\cos 2\omega t - \phi).$$

The first term represents a constant flow of power. The second term represents a double-frequency alternating flow.

In a three-phase system we have in general, in addition to the constant flow terms, the three alternating terms:

in leg A, $\tfrac{1}{2} E_a I_a \cos(2\omega t - \phi_a)$,
in leg B, $\tfrac{1}{2} E_b I_b \cos(2\omega t - 4\pi/3 - \phi_b)$,
in leg C, $\tfrac{1}{2} E_c I_c \cos(2\omega t - 8\pi/3 - \phi_c)$.

If now the phases are balanced so that $E_a = E_b = E_c$ $I_a = I_b = I_c$; and $\phi_a = \phi_b = \phi_c$; these alternating terms can be represented by three equal vectors spaced at 120 deg. to one another, which rotate at twice the

* Paper read before the Institution of Electrical Engineers on December 5.

frequency of the supply (see Fig. 1). As the sum of equal vectors so placed is equal to zero, the alternating components of the power balance one another out when taken for the system as a whole. Thus we get, as Steinmetz has pointed out,* another test of the balance of the loads. If the sum of the three alternating components of the power is zero, the load is balanced in the sense that the single-phase load is on the whole eliminated and the power flows from the generator in an even stream; but if the sum is not zero there is a fluctuating flow of power from the generator.

Elimination of Single-Phase Power Components without "Balance of Phases."—If the conditions (1), (2), (3) and (4) above do not apply, then the alternating components of the power may or not balance out one another. It may happen by chance or design that the amplitude and phase of three alternating power components are such that the three vectors representing them would form the sides of a triangle, as in Fig. 2, with the arrow-heads (showing the sense of the vectors) following one another consecutively. In this case the alternating components of the power balance one another, although it may be that neither the currents nor the voltages are balanced.

In Appendix II there is worked out an example in which the power is balanced according to Steinmetz's definition of balance, although the currents and voltages are not balanced.

Balancers. Stationary Apparatus.—Where a polyphase load has been unbalanced by the addition of a single-phase load, it may be balanced by the addition of a wattless load taken by a choke coil or a condenser. Steinmetz has shown* that where a load is unbalanced and the resultant of the alternating components of the power is equal to $\frac{1}{2} E I \cos (2 \omega t - \phi)$ it is possible to balance the system (according to his definition of balance) by the addition of a choke coil (of no resistance) fed with a voltage $E' \sin (\omega t - \beta)$, where $\beta = \frac{1}{2}\phi + \frac{1}{4}\pi$ and taking a current $I' \sin (\omega t - \beta - \frac{1}{4}\pi)$, where $E' I' = E I$. Or the system may be balanced by the addition of a capacity fed from the voltage $E' \sin (\omega t - \beta)$, where $\beta = \frac{1}{2}\phi - \frac{1}{4}\pi$.

If we apply this method to the balancing of a three-phase circuit which is carrying a single-phase load, it will be found that for some loads the addition of the choke coil gives a true balance, according to the definition above; but that for other loads the balance (while it is such as to bring to zero the resultant alternating components of power) is not such as to comply with conditions (1), (2), (3) and (4) above.

In Appendix III is given a graphic construction, which shows how it is that the addition of a choke coil in the example given by Steinmetz brings about a balance of phases. If, however, we apply Steinmetz's method to the case of a single-phase furnace fed from a three-phase supply, when the furnace is taking a current lagging 45 deg. $= \phi$, we find that we do not necessarily get symmetrical currents. Whether we do or not, depends upon the particular voltage components from the three phases that we take to build up the voltage $E' \sin (\omega t - \beta)$.

In Appendix IV is shown a case where the addition of a choke coil fed from the voltage $E' \sin (\omega t - \beta)$, and taking such a current as to bring the sum of the alternating components of power to zero, nevertheless fails to bring about a balance of phases as defined.

It is, however, possible by taking three transformers of suitable ratios, to build up the voltage e' from components e_a, e_b and e_c such that the final currents in all phases are exactly balanced when the choke coil is in circuit with e'. The components of the voltages to be taken in order to meet this condition are seen from Fig. 37 in Appendix V.

It will be seen that the addition to the system of the choking coil in question, while it brings about a balance, increases the wattless load on the system. Now that condensers of large capacity can be manufactured at fairly reasonable prices, it would be possible to use a condenser instead of a choke coil, with the effect of improving the power factor at the same time as balancing its load. In Appendix VI is given the construction which shows how it is possible to balance the currents as well as to reduce the alternating components of the power to zero in the condenser case (see Figs. 39 and 40). Such an arrangement, however, has the drawback (apart from its first cost) of requiring to be switched in and out with the furnace load. If it is left always in circuit it will produce as much out-of-balance when the furnace is not taking current as the furnace produces when no compensator is employed. It would, of course, be possible to make automatic gear for switching in more or less capacity as the load on the furnace changed; but such automatic switching arrangements are not looked upon with favour by electrical manufacturers.

Balancers. Running Machines.—A running machine such as a synchronous motor or asynchronous motor is able to take energy from the circuit at one part of a cycle, store it as kinetic energy, and return it to the circuit at another part of the cycle. In this way it is able to neutralise the alternating component of the power mentioned above. Any symmetrical three-phase motor or generator running on the system and having an armature of low impedance will help to balance the voltages on a system when the voltages are unbalanced. Such a machine balances the voltages by taking unbalanced currents from the line. These unbalanced currents, multiplied by the impedances of their respective armature circuits, give the unequal voltage-drops that represent the differences between the unsymmetrical voltages e_a, e_b and e_c of the line, and the symmetrical back voltages e'_a, e'_b and e'_c of the motor or generator. If the impedance of the armature is exceedingly low, these differences will be exceedingly small—that is to say, the system will be very nearly balanced.

If the armature impedance is not negligibly small, it is possible to obtain balance by connecting some kind of boosting appliance in series with the balancer to compensate for the impedance drop in the armature. In this way a comparatively small balancer can be compelled to take an unsymmetrical load sufficient to balance perfectly the voltage of the system. The main distinction between different kinds of balancers

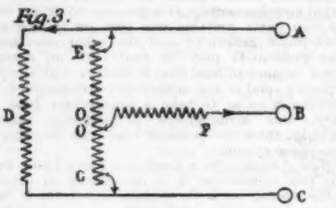


Fig. 3.

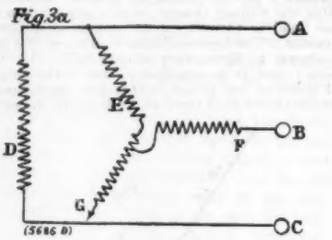


Fig. 3a.

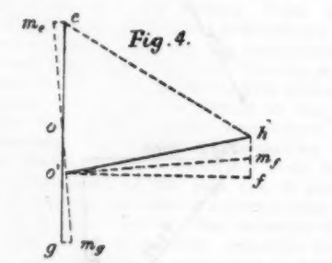


Fig. 4.

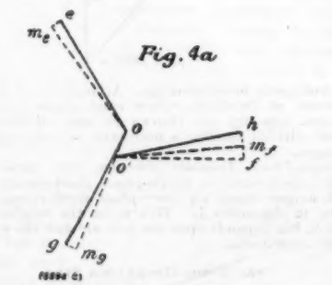


Fig. 4a.

lies in the kind of boosting appliance employed. The methods of boosting may be roughly classified as follows:—

(*a*) Unsymmetrical numbers of turns in the balancer winding.

(*b*) Booster transformer in series with the winding.

(*c*) Addition of choke coils or condensers to some of the phases.

(*d*) Booster generator in series with the winding.

(*e*) The generation of an oppositely-rotating magnetic field of double the frequency.

With any of these methods, the balancer may be either synchronous or asynchronous. A synchronous balancer can be used to correct the power factor of the system, whereas an asynchronous machine usually throws a lagging wattless load on the system.

(*a*) *Unsymmetrical Numbers of Turns on Balancer Winding.*—The first method is illustrated in Fig. 3,* which shows a single-phase load D supplied from a three-phase supply, the terminals of which are A, B and C. A balancer (which may be either synchronous or asynchronous) is shown with its windings E, F, G, connected so as to balance the load. The windings E and G together may form one of the phases of a two-phase generator, F forming the other phase. In this case the number of turns in F is arranged so as to give a symmetrical three-phase voltage at the terminals. Or, if preferred, the winding E, F and G may be wound as an ordinary three-phase generator (Fig. 3A). In either case tappings are brought out from E, G, near the star point so that the inner end of F may be connected in an unsymmetrical manner. Tappings may also be brought out near the outer ends of E and G.

Let us first connect F to the centre point of E G and see what will happen when a single-phase load is thrown on D. To fix our ideas we shall consider the case of a synchronous balancer with the excitation arranged to give unity power factor. If the generators and mains supplying A, B and C had an infinitely small impedance, then whatever single-phase load we might draw the three-phase voltage would remain balanced, and the balancer would run light, taking only a small synchronising current. In practice, the generators have a certain impedance, which (as shown above) causes the voltage A C to fall. The winding E G will then have a small tendency to supply current to D, and the winding F will operate as a motor winding. The synchronous impedance of the balancer will, however, limit the load supplied to D, and it will only be in so far as the voltage on the system is thrown out of balance that any load can be obtained from E G. If now we displace the inner end of F in the manner shown in Fig. 3A, we can obtain a large balancing load from E G while the three-phase voltage remains balanced. The vector diagram is shown in Fig. 4A. For the purpose of this figure, the arrow-heads in Fig. 3 show the directions of currents and E.M.F.'s taken as positive. Moreover, it should be remarked that the phase of the voltage at the terminals of E G is taken as the standard of phase; that is to say, that a vertical line is arbitrarily taken to represent the phase of this terminal voltage, and the phase positions of all other vectors are set off from this vertical line, according to the phase difference between their respective quantities and this terminal voltage. If $o\,e$ and $o\,g$ represent the terminal voltage of O E and O G respectively when the balancer is on load, it is clear that the generated voltages in these windings must be slightly ahead in phase if O E and O G are to supply currents as generators, the phase position of the field magnet being ahead of the terminal voltage the generated voltages may be represented by $o\,m_e$ and $o\,m_g$ respectively. The field magnet as will be seen directly, is forced ahead by the F winding and gives rise to this lead in the phase of $o\,m_e$ and $o\,m_g$. If the load current is nearly in phase with the E.M.F., the impedance drop in O E and O G may be represented by $m_e\,e$ and $m_g\,g$. The vector $o'\,m_f$, which is at right angles to $m_e\,m_g$, gives the generated voltage in F. Now the winding F is carrying a motor load, so that the impedance drop must be set off in a counter-clockwise direction $m_f\,h$. Let the inner end of F be displaced from the star point O to the point O' (Fig. 3), and let the voltage in O O' be $o\,o'$ (Fig. 4). At no load the voltage generated in F will be $o'\,f$. At full load, the generated voltage will be $o'\,m_f$, owing to the displacement of the field magnet, and the terminal voltage will be $o'\,h$. If now the displacement from o to o' downwards is approximately equal to the displacement between h and f, the points e, h and g will fall near the corners of an equilateral triangle; that is to say, the voltages are nearly balanced. In practice the displacement of the inner end of F does not exactly compensate for the displacement of h to f, owing to slight phase displacements caused by the resistances of the circuits. Balance can be more accurately obtained by using the taps at E and G. The drawback to the use of these unsymmetrical connections is that at no load they cause as much out-of-balance as they cure when the load is on. Proposals* have been made for altering the taps on the windings automatically as the load comes on, but this involves rather undesirable complications.

(*b*) *Boosting Transformers in Series with Balancer Windings.*—It is clear that it is possible to compensate for the inductive drop in the balancer windings by injecting electromotive forces of the right amount and phase, by means of transformers, in series with the balancer windings. In 1915 a single-phase furnace project was brought before the British Westinghouse Company, and experiments were made to see how far a synchronous motor could be made to operate as a balancer by means of injected E.M.F.'s. The apparatus was just such as could be found on the test bed at the time, and consisted of a 250-kw. rotary converter acting as a balancer fed from a 300-kw. three-phase star-connected alternating-current generator. The single-phase load consisted of an iron wire rack and a choke coil, and had a power factor of about 0·8. The boosting transformers were the ordinary workshop testing-transformers provided with a large number of taps on the secondary, and were not very suitable for the work. The connections to the terminals of the three-phase generator are shown in Fig. 5. It was found that the rotary converter could be made to balance the currents fairly well. With a single-phase load of 165 k.v.a. on

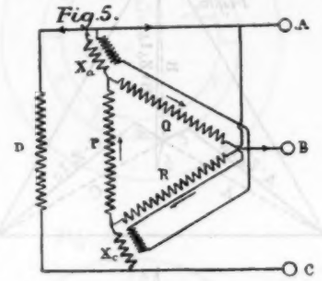
* "The Theory and Calculation of Electric Circuits," page 314.

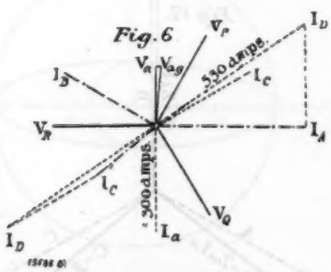
* All the clock diagrams in this paper are supposed to rotate anti-clockwise. It will be seen on inspection of the diagrams relating to the various balancers that in some cases the back E.M.F. of phase A is shown ahead of the line impressed E.M.F. in A and sometimes behind the impressed E.M.F. This is as it should be. In Fig. 4, for instance, it is ahead because the field magnet is pushed ahead by the phase B acting as a motor. In Fig. 6 it is behind because the boosting E.M.F.'s are such as to enable phase A to act as generator notwithstanding the position of the field magnet, which being behind the impressed E.M.F. brings into being a synchronising E.M.F., $V_a V_{ag}$, and this, in combination with the booster E.M.F., gives the desired load on the balancer.

* United States patent specifications Nos. 114,167 and 136,016 of 1916.

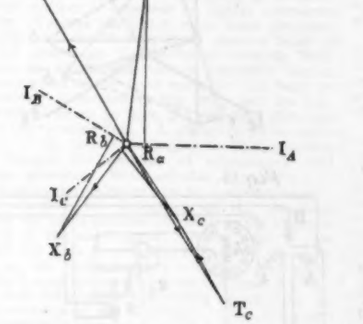
the rack, the currents from the terminals of the alternating current generator were balanced to within 6 per cent. of the mean current. This was good enough for practical purposes, and if it had been possible to get better control of the boosting voltage a better balance could have been obtained. The rotary converter, in addition to balancing the load, provided all the wattless current for the single-phase load, the current from the alternating-current generator being drawn at unity power factor. Owing to the unsteady conditions prevailing at the time, it was not possible to find the exact angles between the various voltages and currents; but there was no very marked departure from the ideal case represented in Fig. 6. Here the vertical line O V_a is taken as the standard of phase, and represents the pressure at the terminal A measured from the star point of the generator. The vectors V_P, V_Q and V_R are the line pressures C to A, A to B, and B to C respectively. The directions that are taken as positive in each wire for the purpose of the clock diagram are shown by the arrow-heads in Fig. 5. The boosting and synchronising E.M.F.'s are too small to be shown satisfactorily in Fig. 6 and are therefore shown to a different scale in Fig. 7. Neglecting these for the moment and returning to Fig. 6, we may consider the generator and motor functions of the balancer separately, and afterwards combine the generator and motor currents to obtain the actual current at each terminal.

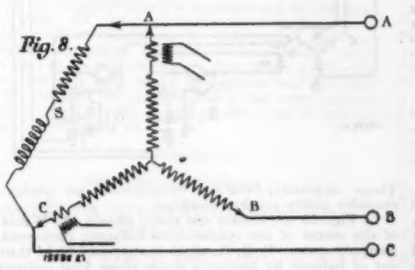
We have in the first place a current of 530 amperes





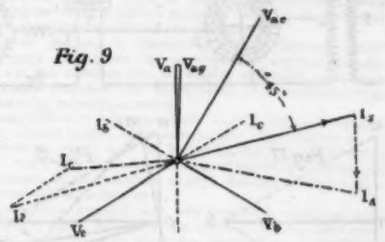
supplied to the single-phase load D; this is shown by the vector O I_D lagging 36 deg. behind the voltage V_P. Then we have the three motor currents I_a, I_B and I_c flowing from the three-phase generator into the balancer, each in direct opposition of phase to the star back-E.M.F.'s of the balancer. As the efficiency of the balancer in this experiment was very low, these motor currents were about 300 amperes, giving an input of $3 \times 300 \times 180 = 162$ kw. for a single-phase output of $530 \times 310 \times 0{\cdot}8 = 132$ kw. In combining the generator and motor currents we must of course have regard to the arrow-heads in Fig. 5. According to the conventions chosen, I_d is a positive current when flowing in D in the direction of the D arrow-head; and as the arrow-head at X_a runs concurrently with it, I_D and I_a must be added, as shown in Fig. 6, to get the actual current I_A. The arrow-head at D is, however, opposed to the C arrow-head, and so to get the current at C we must subtract I_D from I_C. This gives us O I_C, shown by the chain-dotted line. The current at B is, of course, I_B. Thus we get the currents I_A, I_B, and I_C that would flow in a star-connected balancer. The fact that the rotary converter is mesh-connected does not affect the deductions made below. The inductive drop in the armature of the converter was about 3·8 volts for each 100 amperes drawn from a slip-ring; and the resistance drop was 0·35 volt for each 100 amperes. Referring now to Fig. 7, we set off the resistance drop O R_a along the vector I_a, and the reactive drop $R_a X_a$ to get the impedance drop O X_a in phase A. If this impedance drop is to cause no disturbance to the balance of the voltages, it must be supplied by the boosting transformer (shown at X_a in Fig. 5) acting in conjunction with the synchronising voltage V_s V_{sy} (see above. The synchronising voltage $T_a X_a$ (due to the displacement of the field magnet behind the terminal voltage) is transferred from Fig. 6 and drawn to the large scale of Fig. 7. We then find that if the boosting transformer supplies the voltage O T_a, the two voltages O T_a and $T_a X_a$ will supply the required impedance drop. In the same way we can find the boosting voltage O T_c required from transformer X_c. It will be seen that for this particular single-phase load the boosting voltage is almost parallel to the voltage V_Q (Fig. 6). The primaries of the boosting transformers were connected to the terminals A and B, and the number of turns was adjusted so as to give the



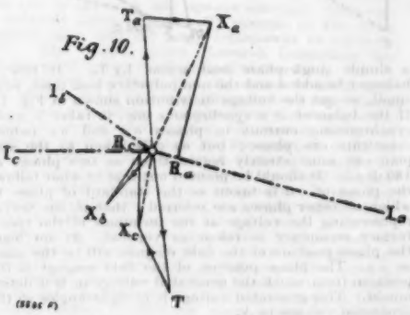


best possible balance. This arrangement, however, makes no provision for balancing the resistance drop in phase B. The reactive drop in phase B is almost balanced by the synchronising voltage. This is because the displacement of the field magnet behind the terminal voltage becomes automatically greater and greater, until the synchronising voltage is great enough to supply the requisite motor current, which in this case was 300 amperes. It was found that if the single-phase load was thrown off with the boosting transformer still in action, the rotary converter took from the alternating-current generator an unbalanced load of a magnitude comparable with the single-phase load thrown off. In fact, for every change of the single-phase load it was necessary to alter the taps of the boosting transformer, and for different power factors of the single-phase load it was necessary to take different combinations of phases in order to supply a boosting voltage in the right phase.

A project for a balancer for a 2-400-k.v.a., 0·7 power factor, single-phase furnace was considered in some detail, in order to arrive at the approximate cost and efficiency of such a balancer, and to ascertain the amount and phase of the boosting voltages. The balancer proposed in this case was to be of the synchronous type, built exactly like a synchronous motor, with a heavy amortisseur and with a rather large section of copper in one of the phases of the armature. It was intended that the balancer should carry an excitation sufficient to raise to unity the power factor of the load on the three-phase system. The circuit diagram, with the directions taken as positive in each wire, is shown in Fig. 8. Fig. 9 gives the clock diagram for the balancer when balancing a single-phase load of 2,400 k.v.a. at 0·7 power factor. The pressure of the three-phase mains is 6,600 volts. The figure is drawn to the scale of 1 mm. = 240 volts; 1 mm. = 12 amperes. The single-phase current I_s amounts to 364 amperes, lagging 45 deg. behind the voltage V_{ss}. The currents I_a, I_b, I_c are the balanced three-phase currents taken from the supply mains, opposite in phase to the no-load back E.M.F.'s V_a, V_b and V_c generated in the balancer. The sum of I_B and I_c gives the vector I_A the actual current in phase A of the balancer. The difference between I_s and I_B gives I_C the actual current in phase C of the balancer. The current I_B is, of course, the actual current in phase B. This disposition of currents is brought about partly by the boosting E.M.F.'s and partly by the synchronising E.M.F.'s operating between the motor and the generator. The synchronising E.M.F. in phase A is shown by the short vector V_a V_{sy} approximately at right angles to O V_a. O V_{sy} gives the phase position of the generated voltage in the balancer on full load. It should be noted that as the balancer is running as a motor the phase position is as shown, even on the phases of the balancer that are to operate as generators. It is by virtue of the boosting E.M.F. shown in Fig. 10 that phases A and C are able to operate as generators. The reactance drop in one phase of the armature of the balancer is calculated to be about 11·5 per cent. of the 3,800 volts generated in that phase, for a current of 364 amperes. The resistance drop, including eddy-current losses, will amount to about 2 per cent. In order to arrive at the amount and phase positions of the required boosting voltages, we must refer to Fig. 10, which is drawn to a larger scale; namely, 1 mm. = 18 volts; 2 mm. = 18 amperes. The currents I_A, I_C and I_B are transferred from Fig. 9. We mark off O R_a to give the resistance drop in phase A, and $R_a X_a$, at right angles, to give the reactive drop in phase A; so that X_a O gives the impedance drop. To overcome this, it is necessary to have a boosting E.M.F. O T_a, which when added to the synchronising E.M.F. $T_a X_a$ gives a voltage of right amount and phase to overcome the impedance drop X_a O. Similarly in phase C the boosting voltage O T_c must be injected in order that, combined with the synchronising voltage $E_c X_c$ it may overcome the reactive drop X_c O. The synchronising voltage O X_b is sufficient to drive the current O I_B through the reactance of phase B. From this it is seen that the requisite boost in phases A and C amounts to about 400 volts, and its phase is 10 deg. in advance of the E.M.F. V_a. It might be supplied by a transformer connected between terminal A and a tapping on winding B near the star point.



The calculated efficiency of a balancer of this size was 93 per cent., as against an efficiency of 87 per cent. for a motor generator. The estimated cost (war-time prices) was 65 per cent. of the cost of a motor-generator to do the same work. As it would be necessary to supply, in addition to the balancer, a transformer to reduce the pressure from 6,600 volts to 220 volts, the cost of the balancer with exciter and starter, step-down transformer and boosting transformer, would not differ very much from the cost of the motor generator; and



the combination would have an efficiency only 3 per cent. or 4 per cent. higher than that of a motor generator.

It was thought by the author that it should be possible to combine in one machine the balancing and power-factor-correcting functions of the synchronous motor with the functions of a step-down transformer and boosting transformer. This combination has been made in the balancer described later in this paper.

The drawback to the connection of boosting transformers permanently in series with various phases is, that when the single-phase load is taken off the system the amount of out-of-balance current taken by the various phases is the same as the out-of-balance current that there would be on full load if no boosting transformers had been used. This could be avoided by having adjustable taps on the transformer that could be controlled by hand or automatically as the load came on and off.*

(c) *Addition of Choke Coils or Condensers to Some of the Phases.*—It will be seen in the methods described under the last heading (b) that while we have voltages that are balanced when measured outside the boosting transformers (say at the terminals A, B and C in Fig. 8), the voltages measured at the terminals of the balancer itself are not balanced. A want of symmetry here is necessary in order to make the balancer take its load. There are numerous ways in which this want of symmetry can be produced at the terminals of the balancer by the addition of choke coils or condensers in some of the phases, while at the same time the symmetry of the voltages is preserved at the mains. A typical method due to Lawrence† will serve to illustrate the principle of all these methods. It has been proposed for balancing the voltage at the terminals of a three-phase motor on a locomotive fed from a single-phase trolley line. Here single-phase power from transformer T, Fig. 11, is being converted into three phase power. A rotating balancer A, B, C (which may be either synchronous or asynchronous) is used to

* U.S.A. patent specifications Nos. 114,167 and 136,016 of 1916.

† U.S.A. patent specification No. 110,815 of 1916.

equalise the flow of power. A special choke coil X Y with two windings is placed in series with lines L_a and L_c leading direct from the terminals of the secondary of the transformer. The line L_B is fed from a mid-point of the secondary and passes through one of the phases of a two-phase balancer on its way to the motor. The arrow-heads on the circuit diagram denote the directions on each wire taken as positive for the purpose of the clock diagram. The transformer T may be taken to be supplying power to the three-phase motor M or to any other three-phase apparatus. The distribution of voltage in the three-phase circuit will depend upon the kind of machines connected. We can distinguish broadly three cases :—

(α) Where the load on the three-phase consists of balanced machines (such as synchronous motors) having infinitely small impedance.

(β) Where it consists of dead resistance.

(γ) Where it consists of machines having finite impedance.

In case (α) no balancer is needed, and full load can be supplied from T without upsetting the balance of the voltages. In case (β), if there were no balancer, no current would flow in the line L_B and we should have

Fig. 11.

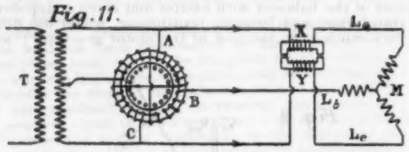


Fig. 12.

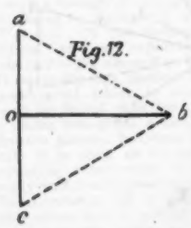
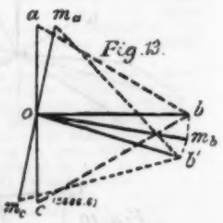


Fig. 13.



a simple single-phase load across L_A L_C. If now a balancer be added and the non-inductive load made very small, we get the voltage distribution shown in Fig. 12. If the balancer is a synchronous one, it takes a small synchronising current in phases $o\,a$ and $o\,c$ (which constitute one phase ; but as o is taken as the star point we must strictly regard them as two phases at 180 deg.). It should be pointed out that in what follows the phase of $o\,a$ is taken as the standard of phase to which all other phases are referred ; that is, the vector representing the voltage at the terminals of the transformer secondary is taken as vertical. At no load, the phase position of the field magnet will be the same as $o\,a$. The phase position of the field magnet is the position from which the generated voltage in B is determined. This generated voltage is at right angles to the generated voltage in A.

If now the load is increased, B will begin by taking its share of the load, and in acting as a generator will pull over the field magnet to, say, a position such as $o\,m_a$ in Fig. 13. Phases A and C will now be acting as motors. The phase of the generated voltage in B takes up a position such as m_b. As there is a motor load on windings A and C, the armature reaction $m_a\,a$ added to $o\,m_a$ gives the terminal voltage of A at $o\,a$, as before. The armature reaction in B is $m_b\,b'$, so that the terminal voltage of B is $o\,b'$. This displacement of the vector $o\,b'$ in the case of a resistance load does not have much effect upon the load taken by each phase, because that is chiefly controlled by the resistance in circuit ; but if the resistance is replaced by a running machine having a small impedance in its windings the displacement of $o\,b'$ tends to take the generator load off the phase B, so that in the ordinary way, if nothing more is added to the apparatus, the balancer will not take much load until the phases of the receiving machine are distorted by a single-phase load by an amount corresponding to $b_b\,b'$.

Now consider the effect of putting a choke X Y in series with L_a and L_c, as shown in Fig. 11. Let the load consist of a symmetrical three-phase resistance. So long as the voltage phases are balanced, this three-phase resistance will take equal currents at 120 deg. apart from each of the lines. Let these currents be I_a, I_b and I_c shown in Fig. 14 drawn from the true star point O'. The coils on X Y (for forward currents, according to the arrow-heads in Fig. 11) are wound so as to give opposing magnetomotive forces on the choke coil. We must therefore reverse one of the vectors, say I_c, in getting the sum of the magnetising effects of the two coils. This is shown in Fig. 14 by the vector $I_a - I_c$. The reactive voltage on the choke coil is nearly at right angles to this magnetomotive force, and is shown at O' $x = a\,a' = c'\,c$. Adding O' x to $o\,a$ we get $o\,a'$, and subtracting O' x from $o\,c$ we get $o\,c'$. We now see that the voltages between the terminals of the resistance $a'\,b'$, $b'\,c'$ and $c'\,a'$ are symmetrical. There are, of course, several minor difficulties. For instance, when the load is a running machine the phase of the load current may not be such as to give the required correction ; but roughly the choke coil works in the right direction, and theoretically it should always be possible, by a suitable arrangement of choke coils and condensers, to bring the added voltage $a\,a'$ and $c\,c'$ into the right phase. The advantage of this method over the boosting-transformer method is that the injected voltage in the choke coil rises automatically with the load. Instead of electrostatic condensers it is of course possible to use electromagnetic machines such as synchronous motors and phase advances.*

(δ) *Booster Generator in Series with the Winding.*—It is clear that, instead of using boosting transformers in series with the various phases, it is possible to use a synchronous booster. In this way the phase and amount of the voltage injected into each leg can be controlled more easily than with transformers in series. Several methods have been proposed, based upon this principle.† The most widely known is that of Alexanderson, described in a paper read by Alexanderson and Hill before the American Institute of Electrical Engineers‡ in October, 1916. While Alexanderson's booster may from one point of view be regarded simply as a booster injecting E.M.F.'s which compensate for the impedance drop in the balancer windings, Alexanderson himself prefers to look upon the operation as the injection of oppositely-rotating polyphase components.

Fig. 14.

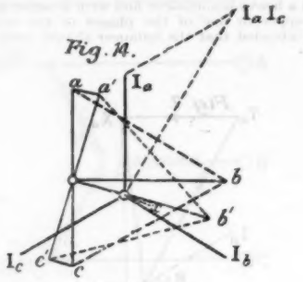
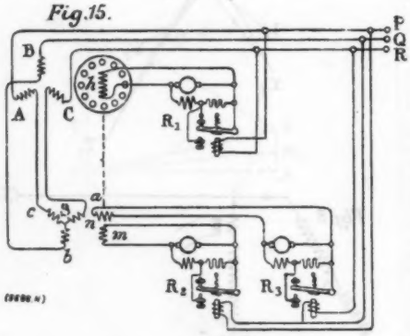


Fig. 15.



These oppositely-rotating components we prefer to consider under another heading.

In Fig. 15 are shown the three phases, A, B and C, of the stator of the synchronous balancer connected to a supply system P, Q, R, which is supposed to be thrown out of balance by having a single-phase load connected between P and R. The function of the balancer is to correct the voltage by supplying current as a generator from phases A and C and taking current as a motor in phase B. These generator and motor currents are controlled by means of a synchronous booster, the stator windings of which are shown at a, b and c. The field magnets of the main machine and booster are rigidly connected on the same shaft and revolve in synchronism with the supply. The booster windings are connected between the inner ends of the balancer windings and the star point S. It will be seen that phases A and C of the balancer are connected to phases c and a respectively of the booster, while phase b of the booster is connected to phase B of the balancer, so that its E.M.F. opposes the E.M.F. of the balancer. The field magnet of the balancer is excited by the winding h fed from an exciter controlled by a Tirrill regulator R_1. The field magnet of the booster has two windings, m and n, like the windings of a two-phase rotor. The continuous current in these windings is controlled by the two Tirril regulators R_2 and R_3 so that the orientation of the magnet field with respect to the iron core of the rotor can be shifted through an arc of 90 electrical degrees, according to the behaviour of the regulators, which in their turn depend upon the distribution of voltage between P, Q and R. It will be seen that the connections shown in Fig. 15 will (for a suitable orientation of the magnetic field of the booster) give a relation of the booster voltages to the balancer voltages such as that illustrated in Fig. 16.

In Fig. 16 the short vectors representing the booster voltages are lettered a, b and c. These are in series with the balancer voltages C, B and A respectively, and have the effect of causing phases A and C of the balancer to take a generator load, and phase B to take a motor load. When A and C are taking a generator load of low power factor, the terminal voltages would be disturbed in phase and reduced by the impedance drops Z_a I_a and Z_c I_c (see Fig. 16), but the phase and value of boosting voltages c and a are such as almost to restore the balance of the voltage at P and R. When B is taking a motor load with a leading power factor, the terminal voltage would be increased to $B + Z_b\,I_b$, but the booster voltage b is subtracted from this and restores the balance between P, Q and R. The vectors may either be laid out as in Fig. 16, in which they radiate from the star point just as the windings radiate in the diagram of connections, or they may be laid out as in Fig. 17, in which form they are more comprehensible in comparison with Fig. 28. The advantage of the booster-generator method of supplying the inductive drops in the balancer over the methods described under headings (α), (δ) and (ϵ) is, that in it the boosting voltages are most easily controlled in value and phase. However, since the boosting generator must have the same number of poles as the balancer,

Fig. 16.

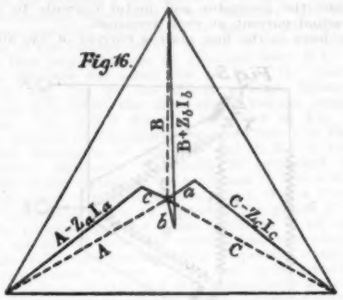
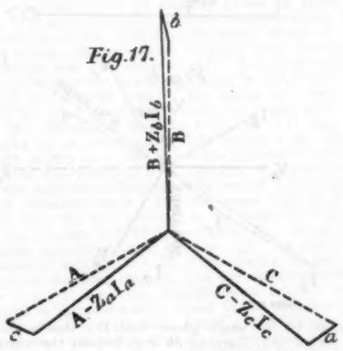


Fig. 17.



it cannot be built very cheaply, even though the output is small ; and the cost of the exciters and regulating gear is by no means negligible.

(ϵ) *The Generation of an Oppositely-Rotating Magnetic Field of Double the Frequency.*—Several methods of balancing single-phase power by supplying currents of double frequency having the sense of rotation opposite to that in the main three-phase system have been described in patent specifications and published writings. As there is a great deal of confusion in writings upon this matter, it may be well, in the first place, to make a precise statement upon the point that is of chief importance in these cases, namely, the effect of an oppositely-rotating magnetic field in a running balancer. And in this connection we must consider the magnetic field produced by a polyphase armature when supplied with unbalanced currents.

Expression for the Resultant Magnetic Field of a Polyphase Armature.—It is not possible to find an exact simple expression for the resultant field of a polyphase generator on load, because the disposition of the armature conductors in slots and the shapes of the iron part of the poles lead to a complex field-form the shape of which changes as the field revolves. Any simple expression involving only the fundamental term of the Fourier series expressing the whole phenomenon must necessarily be of limited application ; but nevertheless it aids us in getting a conception of the main happenings in the machine. For this reason it has been customary for writers upon the subject to regard the armature magnetomotive force of a three-phase armature carrying a balanced load as giving rise to a sinusoidal field distribution superimposed upon the field produced by the exciting winding. Smith and Barling* have shown that the maximum ordinate of the fundamental wave of magnetomotive force under one pole, due to the armature ampere-turns, is equal to :

$$\frac{0{\cdot}43\ I_a\ Z_a}{\text{Number of poles}}$$

* U.S.A. patent specifications Nos. 112,220, 123,031 and 129,976 of 1916.

† U.S.A. patent No. 1,093,594 (1912).

‡ "Single-Phase Power Production," Proceedings of the American Institute of Electrical Engineers, vol. xxv, page 1453.

* *Electrician*, 1914, vol. lxxiv, page 42.

where I_a is the virtual value of the armature current and Z_a is the total number of conductors in the armature. The maximum value of the magnetomotive force in reality changes between the values :

$$\frac{0{\cdot}437\ I_a\ Z_a}{\text{Number of poles}} \text{ and } \frac{0{\cdot}407\ I_a\ Z_a}{\text{Number of poles}}$$

This variation gives rise to a triple-frequency alternating effect which may be regarded as being produced by six stationary single-phase poles per main pole-pair situated at the points where the windings of the various phases lie adjacent to one another. In what follows we shall neglect this triple-frequency alternating effect and confine our attention to the fundamental wave of magnetomotive force.

To fix our ideas, let us consider a two-pole armature having an ordinary full-pitch three-phase winding lying in three phase-bands A, B and C per pole. If the three-phase load is balanced, we may take the armature reaction as giving rise to this fundamental uniformly-rotating field. If the only load is a single-phase load thrown on to terminals A and C, it will give rise to a single-phase magnetomotive force along a path the centre line of which is indicated by the arrow

Fig. 18.

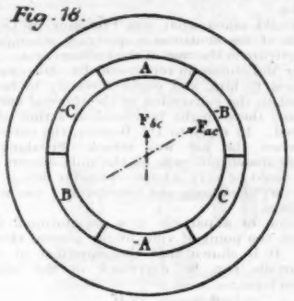
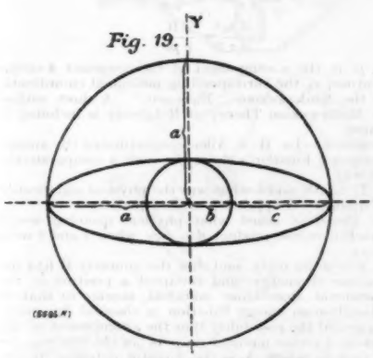


Fig. 19.



O F_{ac} in Fig. 18. If now an additional single-phase load is thrown on another phase, it will give rise to another single-phase magnetomotive force along a path having a fixed centre line. This in combination with O F_{ac} will in general result in an elliptically-rotating field. The addition of a third magnetomotive force changes the shape of the ellipse. In the special case where the single-phase loads on all phases are equal and have equal angles of lag, the ellipse becomes a circle, and we get a simple rotating field, as stated above.

Consider now the general case of any elliptically-rotating field. Let the ellipse be that shown in Fig. 19. Whatever be the slope of the major axis with respect to the horizontal line, it is always possible to take our abscissæ x along the major axis and our ordinates y along the minor axis, and to express the curve in the form $x^2/a^2 + y^2/b^2 = 1$, where a and b are the lengths of the major and minor axis respectively. If we now write $a = b + c$, where c can be found in any given case,

$$\frac{x^2}{(b+c)} = \cos^2 \omega t \text{ and } \frac{y^2}{b^2} = \sin^2 \omega t,$$

$$x = b \cos \omega t + c \cos \omega t,$$

$$y = b \sin \omega t.$$

The elliptically-rotating field can be regarded as consisting of two parts : one part a simple rotating field whose vector is given by the co-ordinates $x_1 = b \cos \omega t$, $y_1 = b \sin \omega t$, and the other part a single-phase stationary field lying along the major axis of the ellipse, given by the expression :

$$x_2 = c \cos \omega t\ ;\ y_2 = 0.$$

Now the single-phase field can be broken up into two oppositely-rotating fields :

$$x_3 = x_4 + x_5 = \tfrac{1}{2} c \cos \omega t + \tfrac{1}{2} c \cos - \omega t,$$

$$y_3 = y_4 + y_5 = \tfrac{1}{2} c \sin \omega t + \tfrac{1}{2} c \sin - \omega t.$$

Adding x_1 to x_4 and y_1 to y_4, we get :

$$x_6 = x_1 + x_4 = (b + \tfrac{1}{2} c) \cos \omega t,$$

$$y_6 = y_1 + y_4 = (b + \tfrac{1}{2} c) \sin \omega t.$$

These form a uniform field rotating forwards, while $x_5 = \frac{1}{2} c \cos (- \omega t)$ and $y_5 = \frac{1}{2} c \sin (- \omega t)$ give us a uniform field rotating backwards. Thus we see that the magnetic field produced in a polyphase machine having symmetrically disposed coils carrying an unbalanced load can be regarded as the resultant of two uniform fields of different amplitudes rotating in opposite directions.

In their paper* read before the American Institute of Electrical Engineers, Messrs. Gilman and Fortescue state that "an unbalanced polyphase system can be resolved into two balanced systems of positive and negative phase-rotation." It will be seen that this proposition is much wider than the one stated above with regard to the magnetic field, and does not seem to be established by the "proof" given by the authors. By employing the symbolic method, the authors merely describe in algebraical terms a stationary clock diagram ; and because of the limitations of the method they employ they cannot establish the proposition.

For our present purpose, however, the proposition established above concerning the magnetic field produced in polyphase machines is sufficient for the understanding of methods of phase-balancing considered under this heading.

An unbalanced load in a polyphase stator produces a backward-rotating magnetic field in the rotor ; and the converse proposition is also true, namely, that a backward rotating magnetic field in the rotor will produce an unbalanced load in the stator. One way, therefore, of making a balancer for a polyphase system is to build a synchronous motor having a special winding on the rotor through which currents can be sent which impress a backward-rotating magnetomotive force. The special winding on the rotor in these machines resembles the winding on a slip-ring rotor for an induction motor. The terminals of the winding may be carried either to slip-rings or along the shaft, according as the special auxiliary generator operating as an alternating-current exciter is separate or rigidly connected to the rotor. Various methods† have been proposed for supplying the double-frequency current that is necessary for producing the backward-rotating field. For instance, an alternating-current generator having twice as many poles as the main machine may have its armature directly connected to the rotor and the connections arranged so as to give the required direction and phase to the rotating field. A change in the strength of the poles of an exciter belonging to this auxiliary generator changes the amount of unbalanced load taken by the balancer. With suitable automatic gear of the Tirrill type the balancer can be made automatic. In another method the armature of the auxiliary generator has the same number of poles as the balancer and is driven at the same speed, but the poles of this generator are fed with three-phase current of the same frequency as the main supply. These three-phase currents (which may be in series with the load) produce a magnetic field rotating in a direction opposite to the direction of rotation of the armature. Thus a double-frequency current is produced in the winding of the rotor of the balancer which is proportional to the three-phase load. All these methods involve the use of several auxiliary machines in addition to the main translating apparatus required to furnish the single-phase load at its right voltage ; and in the single-phase furnace projects with which the author was concerned they did not give the characteristics that were required, and were ruled out in favour of the type of balancer falling under heating (5).

(To be continued.)

NOTES ON REGULATIONS FOR ARC WELDING.‡

By H. M. SAYERS, Member.

ELECTRIC arc welding has recently come into use for a variety of purposes and shows promise of extensive developments. The practice at present is mainly empirical. In view of the possibilities of its application to shipbuilding, one of the Admiralty departments has set up an Electric Welding Research Committee, including a number of unofficial members representing important interests who offered to render voluntary assistance in the development of electric welding.

One of the points which has come before the committee is the question of regulations in respect of (*a*) safety of operators, (*b*) conditions of supply ; and it has been thought essential to have a discussion in order to get the views of members of the Institution on these matters.

The Home Office at present has made no regulations, but is keeping an eye on the processes and, it is understood, wishes to obtain the views of the industry. The Board of Trade has no regulations specifically dealing with welding, but it is clear that some modifications and additions to the existing regulations may be required. In both cases it is desirable that there may be no regulations issued which may be found to hamper progress.

A very large and influential Research Committee has been formed in the United States. It is communicating all its proceedings and reports to the Admiralty Committee, and among them the discussions and reports on regulations.

The Admiralty Committee has already drawn up a skeleton form of regulations based on experience in this country and the communications from the United States, which are set out below.

This paper is therefore brought forward to introduce a discussion, and to set out the points as they at present appear to arise in practice.

WELDING REGULATIONS.

It may be said that arc welding has been in use in this country for over twenty years, but its extension to heavy work and the use of metallic electrodes are of more recent date.

Necessary regulations are conveniently divided into two heads :—

(1) Regulations affecting the safety of operators and workers in their vicinity.

(2) Regulations affecting the reliability and regulations of general supply systems.

Taking the first heading, there are two main points :—

(*a*) Protection of operators and neighbouring workers from the effect of the radiations from the arc.

(*b*) Protection from shock.

(*a*) *Protection from Radiation.*—Under the first heading it is well known that the light from a naked arc has a serious effect upon the eyes and the skin. This is more serious with the iron arc than with the carbon, as the iron-arc radiation is richer in rays of short wave-length, including ultraviolet rays, which are specially detrimental. Welding arcs require large currents, *e.g.*, a No. 10 welding rod requires up to 120 amperes, and as the extension of the arc to heavier work is clearly foreshadowed, arcs carrying several hundred amperes have to be reckoned with in considering protective appliances.

Where welding is carried out in a factory under stationary conditions the provision of screens, masks, &c., for the welders can be readily arranged, and each operator's position can be isolated from neighbouring workers by suitable screens.

More difficulty arises in repair work, such as is carried on in marine boilers, ship spaces, &c. The object to be attained in every case is, however, that arc radiations shall not reach the eyes or skin of either the operators or persons in the vicinity, except through screens which obstruct the injurious rays.

The welder himself and any assistant must be able to see his work, and it is therefore necessary that such screens as they use shall be reasonably transparent to ordinary light. It has to be remembered that the skin of the hands, arms, face and neck needs protection. This can be given by any opaque material. Glass can be obtained which is practically opaque to the most injurious rays, and yet fairly transparent to ordinary light. The United States Research Committee has recommended certain combinations of this kind.

It is clearly important that the screen or mask used shall be such as not to restrict the operator's movements or to cause discomfort. Goggles protect the eyes only. Masks are in use which protect the face as well, but masks are open to objection on the point of comfort. A screen held in the left hand carrying a sufficient area of suitable glass, and an apron to shield the left arm, are satisfactory for stationary work. It may not prove so good for shipbuilding and repair work where the left hand may be required for other uses.

There is no doubt a danger radius from an arc of given power, beyond which no screening is necessary in respect of eye and skin protection. But intense lights within the usual field of vision are objectionable in any working place, quite apart from directly injurious effects, so that the screening-off of welders in factories seems desirable in any case. In shipbuilding it is probable that whilst welding is in progress on any section all the near-by workers will be welders and their mates who will have their individual protection.

In repair work, especially in ship spaces, exigencies of time may require other workers to be employed close to the welders, and perhaps the only possible regulation would have to be in the general terms that efficient shielding from the arc must be employed in such cases.

It may be said that whilst the short-length waves are responsible for the damage to the eyes, and some of that to the skin, the long-wave or heat radiations from powerful arcs also produce sunburn effects on the skin, which must be guarded against. This effect is, however, essentially of short range.

(*b*) *Protection from Shock.*—The pressure across a welding arc is quite low. Both for direct and alternating-current arcs it is of the order of 25 volts to 30 volts. But there is always a steadying resistance or choker in series, and when the arc is broken there is the full supply pressure on the electrode. It is at this time that there is more danger of shock, both because of the higher pressure and because the electrode is not visibly dangerous. It may be laid on the bench or any other handy place and inadvertently touched.

It has to be remembered that in working from a stage, &c., the danger of shock is from indirect effects such as those causing a start or stumble, loss of balance. With direct-current arcs there need be no danger if the supply conditions are properly adjusted ; 100 volts is the maximum supply pressure necessary either for carbon or for metallic electrodes, including steadying resistances, and 100 volts direct current will not make a man start or stumble. Therefore, as regards direct-current welding, the maximum voltage needed is below the danger point, and it is only necessary to limit the supply pressure to some such figure as 100 volts. Even 200 volts (which it may be convenient to employ where welding is only done occasionally) can hardly be called dangerous.

In the case of alternating-current welding the conditions are rather different ; whilst the actual arc voltage as shown by a voltmeter is quite low, 30 volts to 35 volts, practice shows that a considerably greater circuit voltage

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* "The Balancing of Single-Phase Power," Transactions of the American Institute of Electrical Engineers, vol. xxxv, page 1431.

† U.S.A. patents Nos. 108,567, 113,454, 113,455-6, 113,457, and 117,641, of 1916.

‡ Paper read before the Institution of Electrical Engineers on December 12.

must be available. One manufacturer puts this at 110 volts. The minimum stated by another is 65 volts. This matter is under special investigation, and it need only be said here by way of explanation that an iron arc distorts the E.M.F. wave, giving a sharp rise at the beginning of each alternation. Presumably the supply wave must be able to give this peak much in advance of its own peak. It must meantime be accepted that at least 65 volts is needed for alternating current welding. This pressure is capable under certain conditions of giving a severe shock. A welder is certain to have his skin damp with perspiration, which is one condition favourable to a shock. Therefore, to touch a live electrode may have serious consequences, especially for a man working on a staging.

A welder will normally wear a protecting gauntlet of leather, so that there is little risk of shock through the hands unless working in conditions leading to wetting of the gloves. It may perhaps be necessary to lay down the rule that for alternating-current welding the gloves must be waterproof. The most likely chance of getting shocks seems to be when the electrode is laid aside and the welder has his hands bare. It is suggested that this danger can be averted by a "no current" circuit breaker in the circuit, which could be cut out by a pedal switch for the purpose of restarting the arc. The "no current" breaker would serve another useful purpose in preventing the use of too long an arc, which makes bad work.

It is submitted that both for alternating-current and direct-current welding the work should always be earthed, or connected to the earthed pole of the supply circuit.

It should be a rule that a proper hook or receptacle should be always provided for an electrode not in actual use, and should always be used. This guards against shock, burning and unintentional short circuits by contact with the work, and is as essential for work under temporary conditions, repairs, &c., as in a factory. Possibly this rule might dispense with the "no current" breaker in alternating current work. The flexible lead to the electrode needs a little consideration. It must necessarily be somewhat heavy in copper section. The insulating covering must be strong and flexible. Armouring is scarcely admissible on account of weight and stiffness. It should be readily detached from the connecting socket, for ease of exchange, and there should be a switch or breaker between the supply and socket.

The insulation of the flexible near the electrode holder is exposed to considerable heat, conducted and radiated. It must not be damaged by this heating.

The steadying resistances require just the same precautions as resistances for arc lamps, starting and regulating resistances, but as the currents are heavy and pass during the whole of the welding operation ventilation must be good. These restrictions, chokers, &c., must be capable of carrying the short-circuit current without rising to a dangerous or destructive temperature. The design presents more difficulty in portable equipments for repair work, &c., than for stationary equipments. The matter only concerns safety regulations in respect to fire risk and accidental contact, and the same regulations as for other similar operations should suffice.

Supply Regulations.

The conditions of welding are not favourable for direct supply from the mains of a supply undertaking. The maximum voltage needed, say, 100 volts alternating current, down to 60 volts direct current, is considerably below most supplies. The condition that the work must be earthed is also objectionable from the point of view of a supply authority. Of course a higher supply voltage may be used by the simple expedient of using a larger resistance in the welding circuit, but this is wasteful and increases shock dangers. On the grounds of economy it is not likely to be used where welding is in constant or frequent use. The temptation to use it is strongest in works where welding is only done occasionally.

The cases of alternating current and direct-current supply differ materially. Where the general supply from the mains is direct current it must be expected that the pressure will be 200 volts or over from each outer to earth. This is much higher than needed, and it brings in a distinct danger of shock, besides being wasteful of energy. It can therefore be excluded from consideration for equipment in steady use. It will pay the user to put in a converting set yielding the desired voltage.

The case of occasional welding may need consideration. From the economical point of view it may pay the user to throw away 75 per cent. of the energy in resistance rather than incur the cost of a converting set. In such cases the safety arrangements must be similar to those provided for alternating-current sets. The supply interests it may be suggested will be sufficiently protected by providing that the current taken shall be limited in the same way as to any other power circuit. It seems obvious that welding supply circuits must be run separately from any other from the consumer's main fuses. It should be arranged that the work connection can only be made to the earthed lead of the supply. But it must be expected that the work will be earthed in many cases, and it is suggested that supply engineers should tolerate this with such reservations as to power to disconnect for testing purposes, &c., as they think necessary to protect their systems. The Board of Trade regulations will need an exception to be made in the same sense.

Where, as in most cases, motor generators are used for supplying direct-current welding sets, the supply mains have better protection, the generators can have characteristics desirable for welding circuits, and the polarity of the electrode can be reversed for special work when desired.

Where single welding units are installed, some such device as the "Langdon Davy" magnetic clutch between the motor and generator is an added protection to the plant. In this case a demagnetising coil is energised by excess current, and in the case of a short circuit the clutch slips promptly and uncouples the generator.

Alternating-Current Welding.

Owing to the cheapness and efficiency of transformers, it may be assumed that these will always be used between the mains and the welding circuit. From safety considerations alone these should be of the two-circuit type and have earth shields.

Where single-phase is given, the supply undertaking hardly needs special protection, excepting those common to other power uses. It may perhaps be thought advisable to require that part of the resistance in the electrode circuit shall be in the form of choking coils to limit the current on striking the arc, and on making accidental contacts between electrode and work which are virtually short circuits.

Where the supply is given from a multiphase system, questions of balancing arise. Obviously the simplest connection is to put the welding transformer across one phase. If a number of welders are in use and they are equally divided between the phases, they will approximately balance each other.

A single-phase supply can be obtained from either two-phase or three-phase systems, loading each phasing. With two-phase three-wire distribution a single-phase supply can be obtained from the two outers, giving 1·414 times the voltage of either phase. This can be transformed in a single-phase transformer to the welding pressure. Whilst this connection loads each phase equally as regards current, the resultant current is out of phase, lagging on one side and leading on the other, reducing the power factor and tending to unbalance the voltage on the two phases.

Alternatively single-phase current can be taken from each phase directly, and where a number of welders are in use this is the simplest and most satisfactory connection, the welders being equally divided between the phases. There is, of course, the probability that unequal numbers will be in simultaneous use on the two phases, producing some unbalanced load.

With three-phase distribution single-phase current can be taken from a three-phase transformer with its secondaries connected in a particular way. This connection gives currents largely out of phase in opposite senses in two of the windings, tending to unbalance the voltage and reducing the power factor.

Welders can obviously be fed from the separate phases, and if a fair number are distributed between the phases the resulting out-of-balance loads will be only those due to differences in the numbers in simultaneous use.

The whole question from the supply point of view is one of magnitude of the effect, having regard to the relative proportions of the welding load and the general load supplied by the power or substation affected. The provision of condensers or other corrective devices on the lagging-current phase may be worth while in large lay-outs.

At the present stage it seems premature to make definite regulations. Supply undertakers would be sufficiently protected by the provision that for welding plants above a certain capacity, varying with local conditions, the method of converting the supply shall be subject to their approval, which shall not be unreasonably withheld.

In both direct-current and alternating-current welding the striking of the arc is potentially the short-circuiting of the leads. It is on a par with the starting up of a motor, but somewhat more favourable, inasmuch as when welding there must be a resistance in circuit and the current can be limited by providing some minimum resistance or choker which the operator's regulating switch does not cut out. Similar regulations to those limiting starting currents on motors will therefore suffice, with the simplification that where a number of welders are in use a single limiting device in the mains is all that is necessary to protect the supply.

THE PHYSICAL SOCIETY OF LONDON.

At the meeting held on Friday, November 8, at the Imperial College of Science, Professor C. H. Lees, F.R.S., in the chair, a paper on "*Low Voltage Arcs in Metallic Vapours*" was read by Professor J. C. McLellan, F.R.S.

The paper describes experiments by Messrs. Hamer and Kemp, students of the author's, at Toronto University. The experiments show that increasing the temperature of the incandescent cathode lowers the voltage necessary to produce arcs in the vapours of mercury, zinc and cadmium. With limed platinum cathodes arcing voltages were not obtained as low as with incandescent tungsten filaments. With mercury it was found possible to strike arcs with voltages as low as 4·75 volts, and to maintain them at 2·84 volts. Corresponding figures for cadmium were 5 volts and 2 volts. To obtain these very low arcing voltages it was necessary to use intensely hot cathodes and a copious supply of highly-heated metallic vapour. With moderately heated incandescent cathodes and a moderate supply of metallic vapour the arcing voltages were given by the Quantum relation $V = h \times (1 \cdot 5,8)/e$, where $1 \cdot 5,8$ is the frequency of the shortest wave-length in the $\nu = 1 \cdot 5\,8 - m\,\mathrm{P}$ series.

Discussion.—Dr. H. S. Allen, referring to the production of single-line spectra, suggested that possibly the non-appearance of other lines of the series might be due to the fact that in the case of these spectra the plate was necessarily much under-exposed, and one was working on the initial slowly sloping part of the exposure-density curve. A very faint line which produced no appreciable photographic effect under these circumstances might, nevertheless, do so if the plate were given a preliminary exposure sufficient to bring its initial density on to the steep part of the curve.

Dr. D. Owen said that the experiments undoubtedly showed that these arcs could be struck with voltages less than that given by the Quantum relation. The result implied that the additional energy came from a source other than the battery. The hot cathode was such a source, and the question was how did the energy become added to that of the battery so as to produce the required total E.M.F.?

Dr. W. Wilson suggested that the investigations of Richardson and his pupils on the work necessary for the liberation of an electron from hot bodies, such as tungsten supplied the necessary data from which to calculate, on the assumption of a Maxwellian distribution, what proportion of the positive corpuscles had sufficient energy to liberate an electron on impact with the cathode.

Dr. Beattie asked what was the magnitude of the current in these arcs. He presumed there was a marked increase when the arc struck.

The President said he was much interested in the explanation of the production of the arc by the impact of the positive electrons on the cathode. This appeared to involve that the area of the electrode would have an effect on the striking voltage. Had this point been investigated?

Mr. J. Guild asked what was Professor McLennan's explanation of the continuous spectrum accompanying the line spectrum in the case of the brilliant arcs.

Professor McLennan, in reply, said Dr. Allen's suggestion was new to him, and ought certainly to be tried. With regard to the conversion of the thermal energy of the filament, there might be chemical action of some sort involved. In reply to Dr. Beattie, the current did increase when the arc was struck. Speaking from memory, its magnitude was of the milli-ampere order. These arcs could be very intense—possibly 50 c.p.

A paper on "*Relativity and Gravitation*" was read by Dr. W. Wilson.

The motion of a particle in a gravitational field is treated from the point of view of the general theory of relativity. It is shown that the equations of motion of the particle can be expressed in the following Hamiltonian form:—

$$\frac{d\,p_s}{d\,\tau} = -\frac{\partial\,\mathrm{H}}{\partial\,x_s},$$

$$\frac{d\,x_s}{d\,\tau} = \frac{\partial\,\mathrm{H}}{\partial\,p_s}$$

where p_s is the s component of the covariant 4-vector momentum, x_s the corresponding positional co-ordinate, and τ the Minkowskian "Eigenzeit." A short outline of the Minkowskian Theory of Relativity is included in the paper.

Discussion.—Dr. H. S. Allen congratulated the author in expressing Einstein's theory in such a comparatively simple way.

Mr. T. Smith asked what was the physical significance of the quantity H appearing in the equations.

The President asked what physical meaning would be attached to the product $d\,x_s\,d\,x_t$ when s and t were different.

Dr. Wilson, in reply, said that the quantity H had the dimensions of energy, and occupied a position in the 4-dimensional space-time manifold, similar to that of the Hamiltonian energy function in classical dynamics. He suggested the possibility that the s component of the co-variant 4-vector momentum p_s of an electron may be equal to $e\,A_s$, where A_s is the 4-vector potential in the neighbourhood of the electron and e is its charge. He could not, without taking up a great deal of time, explain the meaning of the terms $g_{st}\,d\,x_s\,d\,x_t$, $t = /= s$, in the expression for ds^2.

An exhibition of some experiments on Colour Blindness was given by Mr. C. R. Gibson, F.R.S.E.

The apparatus consisted of a lantern to produce a bright beam of white light and a coloured glass which could be slipped in front of it, so as to cut out all the red rays. Various samples of coloured cloths and ribbons arranged in pairs, while quite dissimilar when viewed by the white light appeared perfect matches with the screen interposed, the conditions then being similar to those in the case of a red blind person. He had found in experimenting with wools by this method that many coloured wools were unsuitable for the purpose on account of fluorescence. Thus although no red light fell on them from the apparatus, there was plenty of red in the light reflected by the wools. In these cases, in order to see what the colours would appear to the red-blind man, it was necessary to have the filter between the wool and the eye, and not simply between the source of light and the wool.

Mr. C. C. Paterson mentioned that in the case of signal lamps it was possible to tell red from green, quite apart from their colour, by looking at them indirectly. A green light got brighter off the line of vision, while a red light got fainter.

Mr. J. Guild asked what screen was employed.

Mr. Gibson said that any screen which cut out the red was suitable. He had tried gelatine dyed with the Sanger-Sheppard minus red. This was good enough for visual work, but not dense enough for the lantern. What he used was practically the ordinary "signal green" glass.

The Industrial Reconstruction Council.—A Conference on Restriction of Output will be held under the auspices of the Industrial Reconstruction Council, on Tuesday, the 17th inst., at 6 p.m., in the Hall of the Institute of Journalists, 2 and 4 Tudor Street, E.C.4. The subject will be introduced by Mr. Wilfrid Hill, of Birmingham, a member of the Whitley Committee, after which the discussion will be open. No tickets are necessary.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

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The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

GAS ENGINES, PRODUCERS, HOLDERS, &c.

119,356. A. H. R. Fedden, and Brazil, Straker and Co., Limited, Fishponds, Bristol. Internal-Combustion Engines. (4 *Figs.*) December 19, 1917.—This invention relates to internal-combustion engines of the type in which the cylinders are disposed radially in one, two or more rows. An internal-combustion engine made in accordance with this invention is characterised in that the crankshaft and connecting rods are adapted to be withdrawn collectively from the crankcase axially. The crank-case *a* is provided with deep flanged orifices *b* adapted to receive and support steel linings of the cylinders *d*, *d*. Each of the linings is provided with a flange adapted to rest on the casing *a*, means being provided for gripping the flanges to

Fig.1.

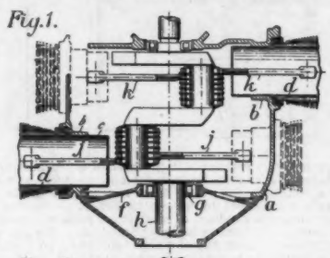
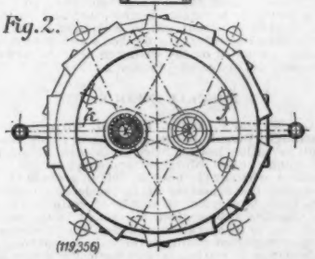


Fig.2.



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the crank-case. At one end of the crank-case is a large opening adapted to be closed by a cover *f*, in which is disposed a bearing *g* for the crankshaft *h*. In the example shown seven cylinders are arranged radially with respect to each crank, *j*, *j*, *j* being the connecting rods with respect to one of the cranks, and *k*, *k*, *k* the connecting rods with respect to the other of the cranks. With an engine made in accordance with this invention, the connecting rods can be assembled on the bench, and further, a solid crankshaft can be used, that is, one that is not split at the crank pins or between the inner supporting bearings. In radial engines with two rows of cylinders, it is generally necessary to finally build up the crankshaft when portions of the crankshaft are in position in the engine. (*Accepted October* 9, 1918.)

119,422. T. G. Smith, Stroud. Internal-Combustion Engines. (5 *Figs.*) May 21, 1918.—According to this invention, the admission valve of an internal-combustion engine is opened against the action of a spring by a lever and a swinging link connected thereto and having its free end travelling upon a track, the inclination of which can be varied by a governor so that the endwise movement of the link will be varied and the extent of opening of the valve thus regulated. *a* is the admission

Fig.1.

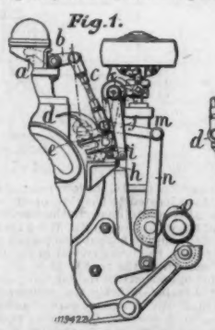
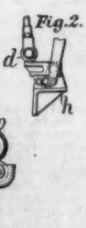


Fig.2.



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valve spindle, *b* the valve operating lever and *c* the swinging link connected thereto; this link, which is adjustable in length, carries a roller *d* travelling upon a track *e*, pivoted on a bracket *h*. Between the bracket and the track is a movable block *i* connected by a link *j* to the lever *k* actuated by the governor; the block *i* is movable towards and from its pivot, and is formed in two parts hinged together by a pin. The axle of the roller *d* is connected to one end of a link *m*, the other end of which is connected to the rocking lever *n*, which is actuated by a cam *o*. As will be understood, if the block *i* is held by the governor in the position shown in Fig. 1, the track will incline downwardly as shown, and all points along its surface will be nearly equidistant from the end of the lever *b*, and, consequently, the movement of the roller *d* along the track will cause practically no movement of the valve and the engine will slow down. With the block and track in the position shown in Fig. 1 by the dot and dash lines, and in Fig. 2, the inner top end of the track is nearer the valve lever *b* than the outer end, and, consequently, the swing of the link *c* will cause full opening of the valve. (*Accepted October* 9, 1918.)

119,275. Vickers, Limited, Westminster, London, and J. McKechnie, Barrow-in-Furness. Internal-Combustion Engines. (3 *Figs.*) September 24, 1917.—This invention relates to two-stroke internal combustion engines. According to this invention, there is provided as close to each cylinder as is practicable, an exhaust controlling valve so actuated as to give full exhaust opening, but closing to check or throttle the escaping gases before the closing of the exhaust ports by the piston. The cylinder A is provided with the exhaust ring B to which the exhaust pipe C, forming a valve casing, is fitted, and the valve shown in the other figures is placed in the exhaust pipe. The spindle of the valve is provided with a bevel wheel with which engages a bevel wheel on the shaft E, the other end of which is driven through bevel gearing from the crankshaft F of the engine. The exhaust passage passing through the exhaust

Fig.1.

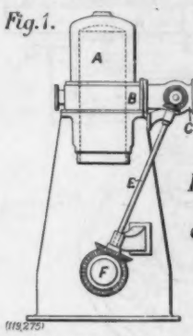
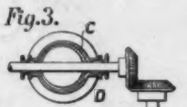


Fig.2.

Fig.3.



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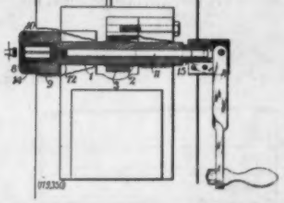
pipe C is provided with the rotating disc valve D mounted centrally upon its spindle, which may be driven as shown in Fig. 1. The disc valve, when in the position shown, does not quite close the passage, and allows the exhaust gases to pass through the narrow annular channel surrounding the disc, this restricted passage giving a pronounced choking action to the gases so that the pressure in the cylinder A at the end of exhaust is substantially above atmospheric pressure. The timing of the valve D is arranged so that the valve approaches the maximum throttling position some time before the engine piston closes the exhaust ports, and the throttling takes place during the entry of the scavenging air. The complete closing of the exhaust by the engine piston occurs approximately at the position of maximum throttling by the valve D. (*Accepted October* 9, 1918.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

119,350. W. Bailey, Birmingham. Chucks. (3 *Figs.*) December 15, 1917.—This invention relates to chucks for thread-milling machines where the work-spindle is rotated by hand, said chucks being of that type comprising a split conical collet having spring jaws adapted to be closed to grip the work by means of an internally-coned outer-closing member surrounding the collet. The spindle 1 having a lead screw 2 engaging a guide nut 3, is adapted to be slowly rotated by hand to give the feed. The chuck consists of a split collet 8 sliding within a recess 14 in the head 9 of the spindle and adapted to engage with an internally-



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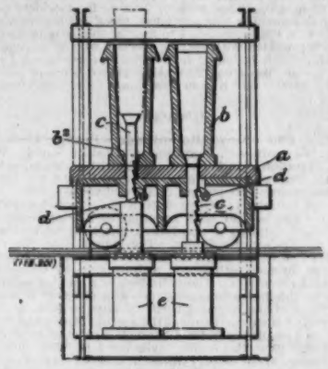
coned ring 10 attached to the head 9. By longitudinal movement of the collet in a forward direction the outer coned surface engages with the interiorly-coned surface of the ring 10 so as to cause the spring jaws to close upon the work. To effect the longitudinal movement of the collet, within the interior of the hollow spindle 1 is a sliding rod 11 engaging at its forward end with a plunger 12 having a head of larger diameter adapted to slide within the recess 14 in the head of the spindle, so as to engage with the end of the collet sleeve. The rear end of the sliding rod 11 is engaged by a short plunger 15 having a head 16 located in an enlargement at the rear end of the spindle. (*Accepted October* 9, 1918.)

MINING, METALLURGY, AND METAL WORKING.

119,301. J. H. Dewhurst, Attercliffe, Sheffield, and H. Crowe, Saltburn-by-Sea. Stripping Ingots. (6 *Figs.*) October 10, 1917.—This invention relates to the stripping of ingots from ingot moulds of the type in which a portion of the mould bottom is removable and capable of being pushed upward by pressure externally applied in order to remove the ingot from the mould. To the top of a casting car is fitted a plate *a*, to form the ingot mould bottom plate, and, at same time, to overhang the sides of the framing of the car and protect the wheels and draw-bar gear from any overflow of molten metal, said plate *a* also being provided with means for holding the ingot moulds in position. The bottom end of each ingot mould is either solid or closed in except for a central hole *b2*, coinciding with a similar hole in the plate *a*, through both of which holes passes a downwardly depending stripping plug *c*. The stalk of this plug is provided with ratchet teeth engaging with which is a pivoted pawl *d*. After the ingots have been cast in the moulds, the car is run to a stripping machine, in connection with which is a series of hydraulic rams *e*, *e*. Each car is in turn passed over the rams and makes contact with a stop, in which position before plugs *c* are directly over the hydraulic rams *e*, *e*, so that when the latter are put into operation the plugs *c* force the ingots upward in the moulds to enable gripping tongs of an overhead crane to take hold of the ingots and remove them from

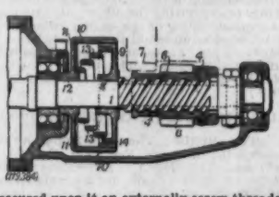


(119,301)

the moulds. If the gripping tongs do not deal with the ingots directly, the car is moved away from the hydraulic rams, but the ingots are still maintained in their raised position by reason of the pawls *d*. After the ingots have been removed from the moulds *b*, the stripping plugs *c* are again lowered by means of an attendant turning the shafts on which the retaining pawls *d* are fitted so that the latter become disengaged from the teeth of the stalks of the plugs *c*, which can then descend into their normal position. (*Accepted October* 9, 1918.)

MOTOR ROAD VEHICLES.

119,384. The Electric and Ordnance Accessories Company, Limited, and F. Wood, Ward End, Birmingham. Self-Starters. (4 *Figs.*) February 2, 1918.—This invention relates to engine starters of that type comprising an electric motor which drives an externally screw-thread shaft upon which is mounted for longitudinal movement thereon, an externally screw-threaded pinion or gear member adapted, by the rotation of the shaft, to be traversed in an axial direction into engagement with a driven member on the flywheel or other part connected with the engine shaft; the shock when the pinion or the like moves into gear being relieved or absorbed by a yielding buffer device. According to the present invention, the buffer device comprises a member which is slidably mounted upon the shaft and which is adapted to be engaged and moved longitudinally by the pinion when it moves into gear, and a fixed member or abutment upon the shaft which the sliding member engages to give a solid drive, a spring or a cushion of air being interposed between the said members to absorb the shock prior to the engagement of the said members. The outer end of the electric motor



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shaft 1 has secured upon it an externally screw-threaded sleeve 4. Upon the screw-threaded sleeve is freely mounted an internally screw-threaded pinion 6 adapted to be traversed in a longitudinal direction into mesh with a driven member 7 upon the flywheel of the engine. Mounted upon the motor shaft is a sliding collar 8 having a circumferential flange 9 provided with an annular wall 14 movable within a dashpot cylinder 10. 13 is a volute-coiled spiral buffer spring interposed between the parts 9, 11. When the pinion 6 moves into engagement with the driven member 7, its inner end engages with the sliding collar 8 and moves the latter inwards along the shaft, thereby compressing the spring 13 in order to cushion the shock due to the driven member taking up the drive. The sliding collar 8 continues to move inwards until it engages with the central boss 12 when further longitudinal movement of the pinion is arrested and a solid drive obtained. Owing to the annular wall 14 of the piston 9 being a close fit within the cylinder 10, the air within the latter is compressed, giving a dashpot effect, and assisting the spring in its cushioning action. (*Accepted October* 9, 1918.)

119,181. W. Dukes, Aston, Birmingham, and The Warland Dual Rim Company, Limited, Aston, Birmingham. Road Vehicle Wheels. (4 *Figs.*) February 5, 1918.—This invention provides an improved road vehicle wheel of the disc type fitted with a detachable rim carrying a pneumatic tyre.

Fig.1.

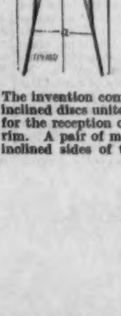


Fig.2.

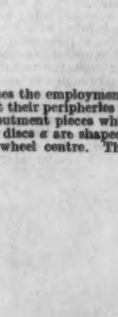
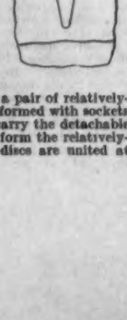


Fig.3.



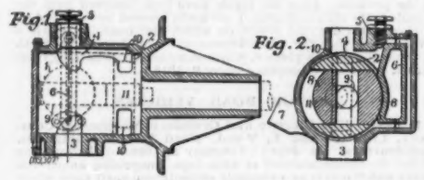
(119,181)

The invention comprises the employment of a pair of relatively-inclined discs united at their peripheries and formed with sockets for the reception of abutment pieces which carry the detachable rim. A pair of metal discs *a* are shaped to form the relatively-inclined sides of the wheel centre. These discs are united at

their peripheries and are stiffened at their peripheral portions by beads *b*. Each disc has integrally formed with it a number of radially-disposed sockets *c* having their open outer ends at the periphery of the disc. Either the whole of the socket may be formed in one disc, the other disc then serving to close the open side of the socket, or one-half may be formed in one disc and the corresponding half in the other, as shown. Whatever construction is adopted the result is such that around the combined discs are a number of equally-spaced sockets into each of which can be inserted and secured a rim abutment piece or support. The detachable rim *e* is constructed to fit over the peripheries of the discs and is provided with seating pieces *f* which rest upon the abutments, suitable fastening devices, such as screws *g* and nuts *h* passing through lugs *i* on the seating pieces, being provided to detachably secure the rim in position. (*Accepted October* 2, 1918.)

PUMPS.

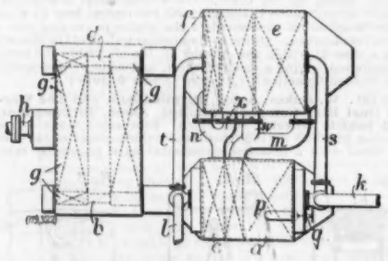
119,307. The New Rotoplunge Pump Company, Limited, Westminster, London, C. Lakin-Smith, Westminster, London, and N. G. Beckwith, Hampton-on-Thames. Pumps (2 *Figs.*) October 17, 1917.—This invention has reference to pumps of that character where liquid from a large cylinder is delivered to a small cylinder and any excess above and beyond that required to fill the small cylinder is returned through a non-return check valve to the suction side of the larger cylinder. The pump is of the rotary plunger type wherein pairs of connected pistons disposed at right angles to each other are reciprocated by co-operation with internal eccentrics. The cylinders 1, 2 of the pump are, according to this invention, constructed of different diameters, and the piston of the larger of them operates to suck in the oil from the source of supply through the suction pipe 3 and deliver it to the other smaller cylinder 2 through a passage 4 cut in the pump casing. Thus the smaller cylinder 2 is filled under the delivery pressure of the larger cylinder 1, and the smaller cylinder must therefore be completely filled at each suction stroke. Seeing that more liquid may be delivered from the larger cylinder than the smaller cylinder can accommodate, a non-return relief valve 5



is provided between the two cylinders so that after the smaller cylinder has been completely filled, the excess liquid will be forced through this relief valve 5 and through the passage 6 back to the suction side of the larger cylinder 1. The pistons 8 of the larger cylinder are reciprocated by co-operation with the eccentric 9 and the pistons 10 of the smaller cylinder are similarly reciprocated by the eccentric 11, whose eccentricity is upon the opposite side of the centre to that of the eccentric 9. Assuming the cylinder body or rotor to be driven in a clockwise direction, the oil will be sucked into the larger cylinder during one-half of the revolution and delivered to the passage 4, whence it passes to the smaller cylinder during the other half of the revolution, and similarly the smaller cylinder will take in oil from the passage 4 during one-half of the revolution and deliver it to the outlet or delivery pipe 7 during the other half. By means of the foregoing the complete filling of the smaller cylinder from which the liquid is delivered as aforesaid to the parts to be lubricated through the delivery pipe 7 is ensured under all conditions and a regular or substantially regular supply of lubricant to the parts to be lubricated irrespective of atmospheric conditions. (*Accepted October* 9, 1918.)

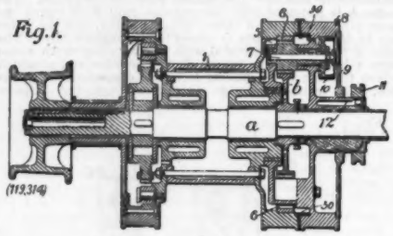
SHIPS AND NAUTICAL APPLIANCES.

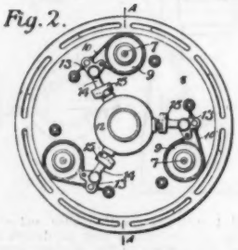
119,322. The British Thomson-Houston Company, Limited, London (*C. G. Curtis, New York, U.S.A.*). **Marine Steam Turbines.** (3 *Figs.*) November 2, 1917.—This invention relates to marine steam turbine installations having an element or elements arranged on each of a plurality of shafts, all of which are arranged by gearing to drive through a common propeller shaft. *a* represents a high-pressure ahead turbine which is mounted on the same shaft *b* as a high-pressure astern turbine *c*. Parallel to shaft *b* is a second shaft *d* on which is mounted a low-pressure ahead turbine *e* and a low-pressure astern turbine *f*. The shafts *b*, *d* are connected through gearing *g* to a propeller shaft *h*. Steam is led to the turbine *a* from the boiler through steam pipe *k* and to the turbine *c* through pipe *l*. The exhaust from turbine *a* passes through pipe *m* to the inlet end of turbine *c* and the exhaust from *c* to the inlet of turbine *f* through pipe *n*. The space *o* between turbines *e* and *f* is in



direct communication with the condenser. Conduit *p* is a bye-pass for permitting high-pressure steam to be supplied to an intermediate stage of the turbine *a* and is controlled by valve *q*. To prevent excessive overload when the valve *q* is opened and at the same time to prevent the backing up of pressure at the inlet end of the turbine *a* owing to live steam being admitted to an intermediate stage, the conduit *p* is fitted with a nozzle which prevents an excessive quantity of steam passing and at the same time reduces the pressure to approximately that of the stage to which it is introduced. In order that the installation may not be rendered totally inoperative through the breakdown of one of the turbines *a* or *c*, conduits *s* and *t* are provided and adapted respectively to connect the low-pressure turbines *c* and *f* with the boiler steam supply. If the low-pressure turbine is supplied with live steam the gearing connecting the turbine with the propeller shaft is overloaded. To overcome this, the conduits *s* and *t* are provided with nozzles which prevent excessive loading of the turbine. When the low-pressure turbines are disabled, conduits *w*, *x* are provided leading from the exhaust ends of turbines *a*, *c*, respectively, and in these conduits nozzles are fitted which serve to back up the pressure of the exhaust so as to reduce the range of expansion in the high-pressure turbines. (*Accepted October* 9, 1918.)

119,314. G. T. Macfarlane, Pinner. Ship's Winches. (5 *Figs.*) October 27, 1917.—This invention relates to ship's winches of the kind comprising a barrel and epicyclic gearing through which power is transmitted to the barrel. The winch barrel 1 is freely mounted on its driving shaft *a* which has keyed thereon a sun wheel *b* into which gear planet pinions 5 carried by a brake drum 8. The planet pinions also gear into a ring of teeth 6 carried by another brake drum fixed to the barrel. Each planet pinion 5 is fixed on its spindle 7 at one end and the other end of the spindle, which is located within the pinion carrier drum 8, is fitted with a small drum 9 furnished with a brake

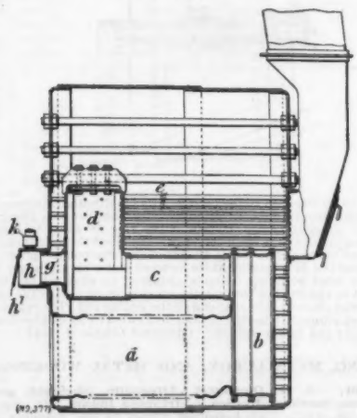




band, the several brake bands being controlled by a collar 11, mounted to slide on the boss 12 of the pinion carrier drum 8 and actuated by a hand lever through appropriate mechanism. The brake bands are each secured to the free ends of the two arms of a bell crank lever 13 which is provided with a third arm 14 terminating in a block 15 formed with an inclined groove in which works a roller on a bar laterally projecting from the sliding collar 11, the arrangement being such that normally the rollers are at the outer ends of the grooves and the brake bands are free from the brake drums 9. When, however, the collar 11 is moved endways the bars move with it and the rollers slide in the inclined grooves and thereby move the bell crank levers 13 in such way as to cause the bands to grip the brake drums 9. (*Accepted October* 9, 1918.)

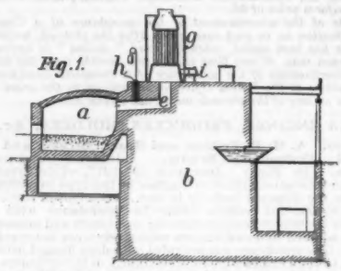
STEAM ENGINES, BOILERS, EVAPORATORS &c.

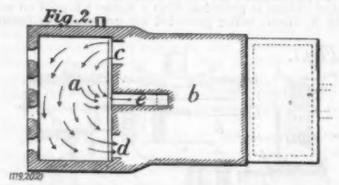
119,377. W. Birrell, Liscard, and J. Donaldson, Birkenhead. Steam Boilers. (3 *Figs.*) January 22, 1918.—This invention relates to a steam boiler structure of the marine shell type, of the kind which comprises a plurality of furnace flues, each having a combustion chamber at its rear end, and a plurality of combustion chambers at the front or firing end of the boiler connected with the said rear combustion chambers and also with the uptake by flues or tubes, all the combustion chambers being surrounded by the water in the boiler. According to this invention each, of the combustion chambers is provided at the front end of the boiler with a manhole tube extending through the water space or wet back and opening out of the front of the



boiler, the manhole tubes being closed by suitable doors or covers. *a* indicates the furnace flues at the rear end of each of which is a small combustion chamber *b*. From each combustion chamber *b* the gases pass by a return flue *c* to a larger combustion chamber *d* at the front of the boiler, both sets of combustion chambers being entirely surrounded by the water. From the several combustion chambers *d*, the gases having been further expanded therein, pass through the boiler tubes *e* into the smoke-box. Each combustion chamber *d* is furnished with a manhole tube *g* which opens out of the boiler front and is closed by a casing *h* furnished with a suitable door *h*1. The said manhole tube *g* would preferably be made of sufficient diameter to permit of the removal of the flue *c* therethrough, as for renewal or repair, although not so shown in the drawings. (*Accepted October* 9, 1918.)

119,202. E. W. Harvey, and The E. W. Harvey Gas Furnace Company, Limited, Westminster, London. Steam Generation. (9 *Figs.*) May 4, 1918.—When power is required in conjunction with a regenerative or recuperative furnace, more particularly a reheating or melting furnace, attempts have been made to economise fuel by using the waste gases to heat a steam boiler. The invention resides in the method of economising fuel in generating power in a regenerative or recuperative furnace installation, which consists in diverting a portion of the flame of the furnace to the fire-box or flues of a suitable boiler. Fig. 1.

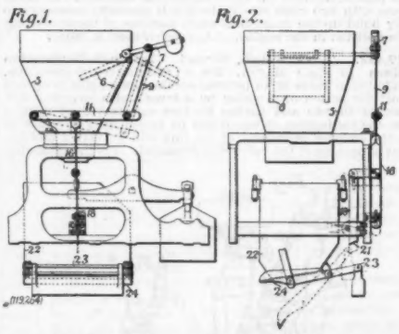




is a diagrammatic vertical section through a regenerative reheating furnace *a* and its regenerator and producer setting *b*; Fig. 2 is a sectional plan. The flame is reversible in the usual manner and is indicated by arrows in Fig. 2, as passing from gas and air ports *c* to products of combustion ports *d*. According to the invention, the furnace has a separate flue *e* through which the draught of a chimney flue of a boiler *g* draws a portion of the flame, as governed by a suitable damper, such as *h*, or when this damper is completely withdrawn, by a damper in the chimney flue itself. The flame enters the fire-box *i* and fire-tubes of the boiler, which is situated on the setting as near the crown of the furnace as may be. (*Accepted October* 2, 1918.)

MISCELLANEOUS.

119,264. W. and T. Avery, Limited, Birmingham, and A. Barraclough, Birmingham. Scales. (2 *Figs.*) August 28, 1917.—This invention has reference to scales for automatically weighing granular or like substances, and simplifies and improves the mechanism whereby the head or bulk of grain in the supply hopper controls the operation of the scale and ensures that only when there is a sufficient supply of grain in the supply hopper to complete a determined weighment, is the mechanism of the scale free for its operation, and that when the supply falls below the predetermined minimum the scale mechanism is locked and the weighing operation is automatically suspended, the operation automatically recommencing when the granular supply has been sufficiently increased. Pivotally mounted within the supply hopper 5 is a plate 6 maintained in position by the grain within the hopper 5. When, however, the supply of grain falls below a predetermined minimum, the plate 6 swings automatically into the supply hopper 5 under the influence of a weighted arm 7. The plate 6 is connected through a link 9 to a lever 11. The lever 11 is connected to a rod 16, which has vertical motion imparted thereto by the pivoting radial motion of the plate 6.



The rod 16 is connected to a vertical bar 18, the lower end of which is bevelled at 21. The bar 18 is located to the side of the weigh hopper 22 and the lower end 21 is approximate to the rear linkage 23 of the discharge door 24 of the weigh hopper 22. When there is a sufficient amount of grain in the supply hopper 5 to permit of the continuing operation of the scale, the lower end 21 of the bar 18 is held out of the path of motion of the rear linkage 23 of the door 24 during its discharging operation (see the full line position, Fig. 2), but when the supply of grain falls below the predetermined minimum the plate 6 automatically moves upwardly under the influence of the weighted arm 7 (see the dotted line position, Fig. 1) and by so doing lowers the bar 18 until the lower end 21 is in the path of motion of the rear linkage 23 of the door 24, and maintains the door 24 in its open position (see the dotted line position in Fig. 2), upon the next discharging operation of the weigh hopper 22, and until the amount of grain in the supply hopper 5 has again become sufficient to permit of a continuing operation of the scale, when the plate 6 is pressed back by the grain to its position against or adjacent to the side of the supply hopper 5, thereby raising the bar 18 and releasing the linkage 23 to permit of a re-starting of the operation of the scale. (*Accepted October* 9, 1918.)